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RECORD BREAKING PAPER AIRPLANES KIT

ANDREW DEWAR

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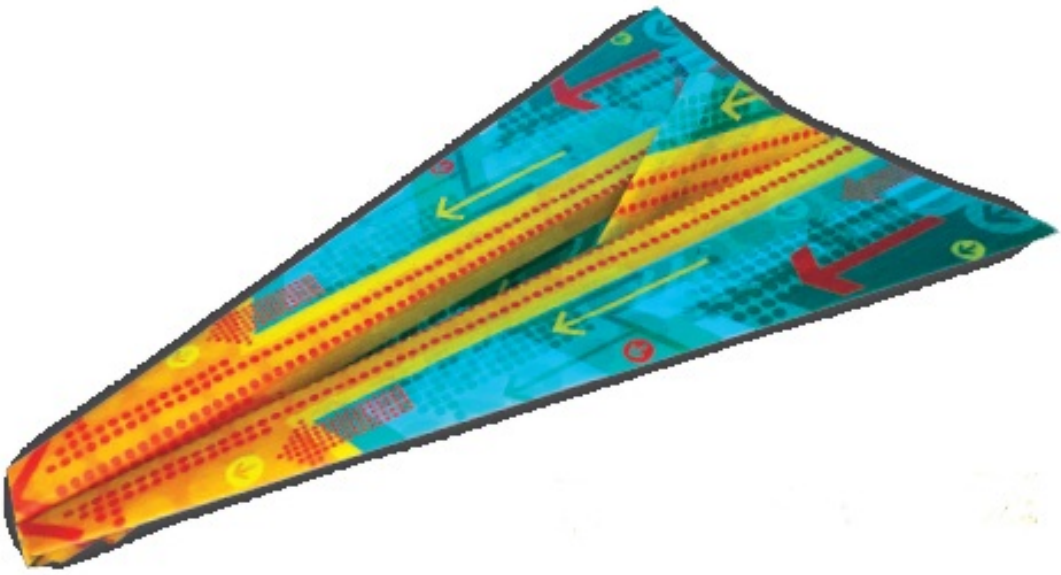

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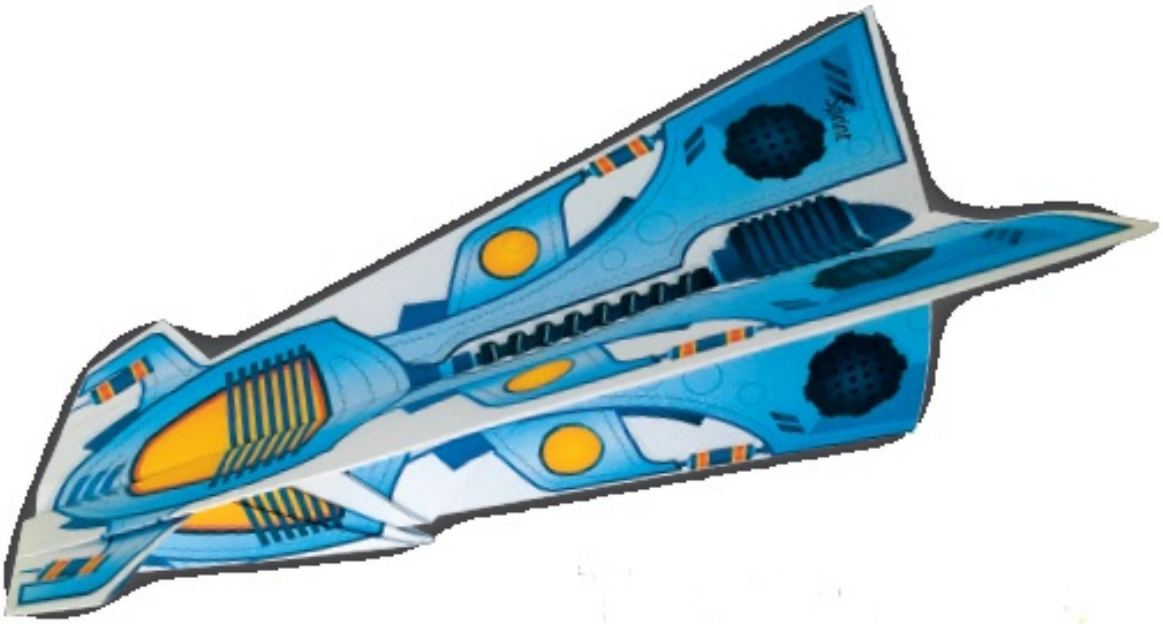

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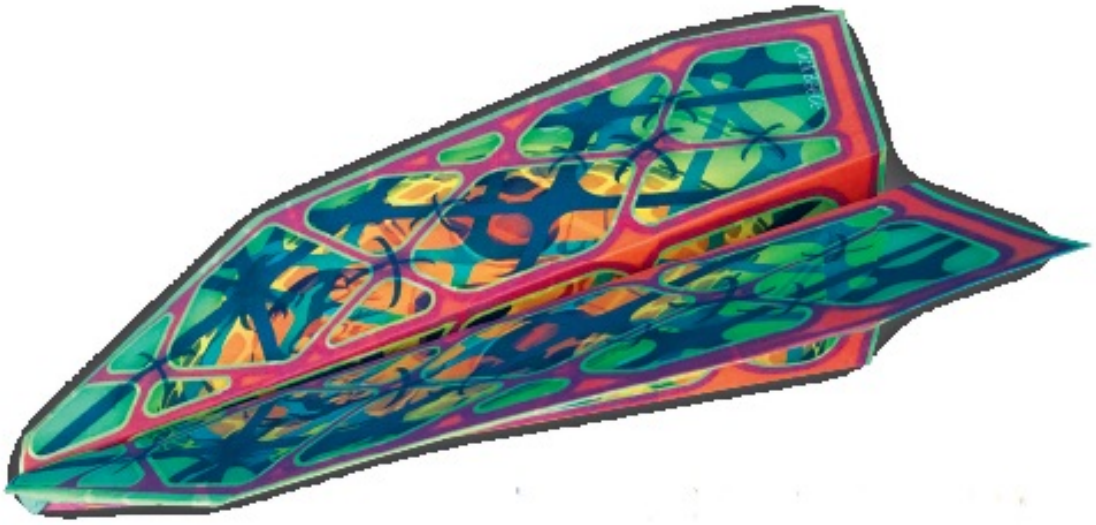

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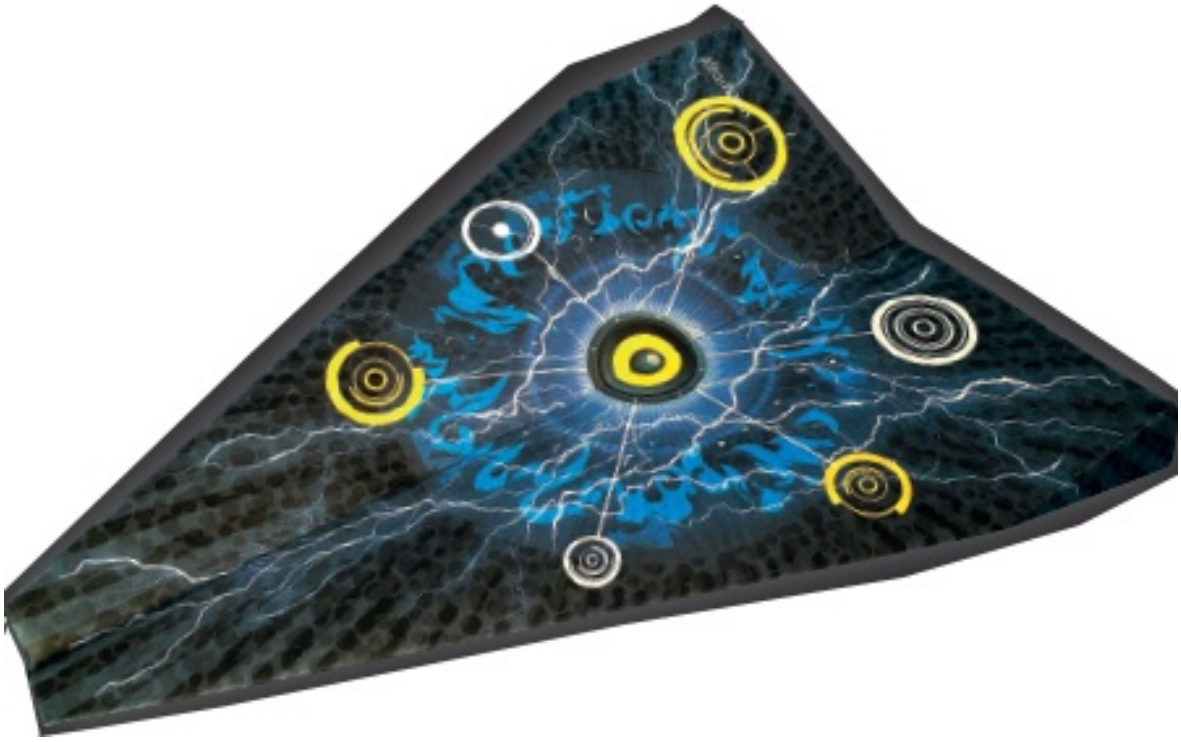

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BE A RECORD BREAKER!

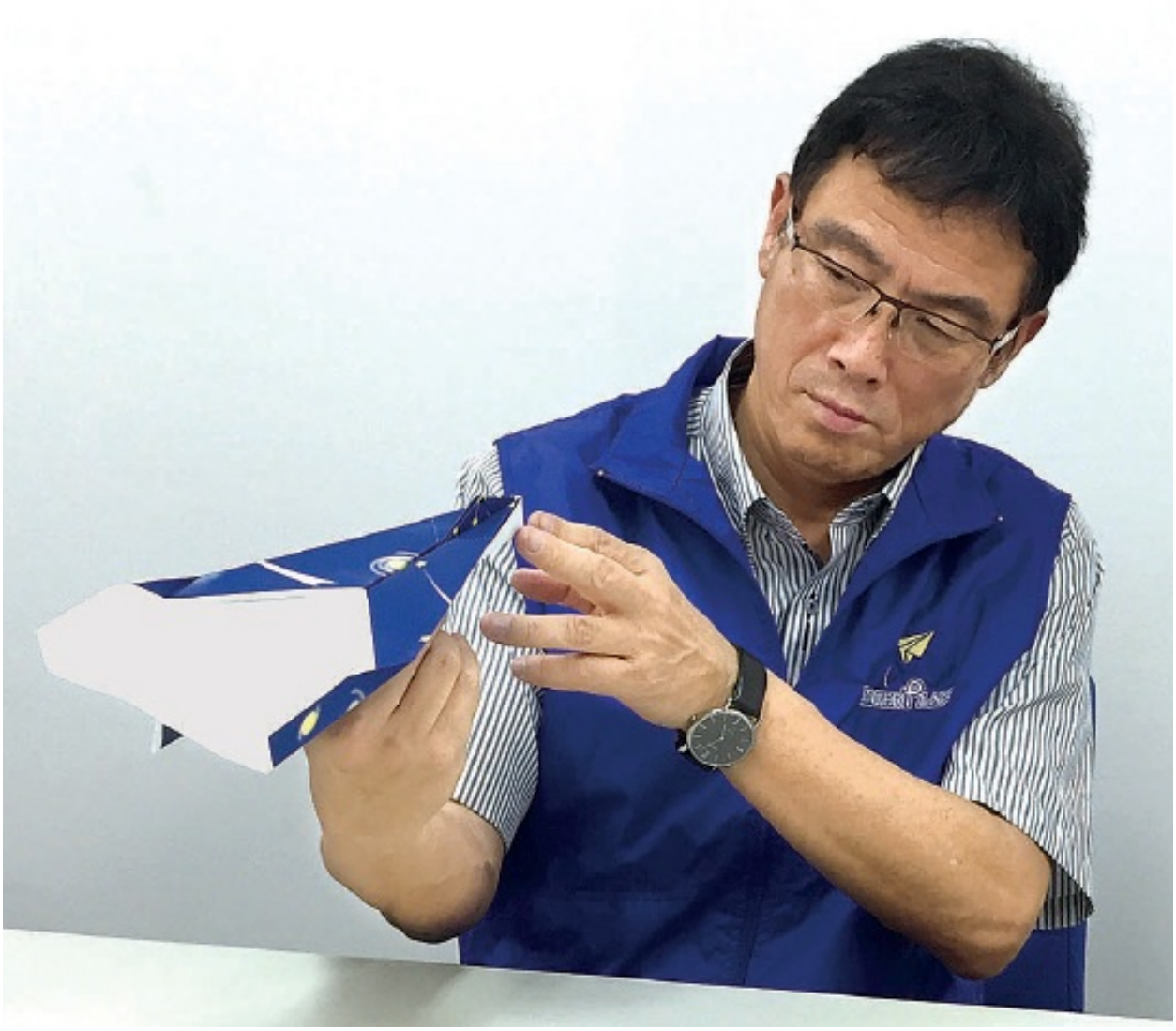
You will soon have a shelf full of high-performance paper airplanes, and you'll know how to trim and fly them. The next natural step will be to think about going after a record. The two big ones, the records that are most coveted, are the flight duration record and the distance record. But you can't just wind up, throw your plane, and claim to be best in the world. There are rules about what kind of planes are acceptable, about how and where the flights can be made, and about how the record is measured and judged. These rules are necessary to make it fair for everyone. I've summarized them here for you, along with some of the reasons for the rules, but both Guinness and I suggest you look them up and read them carefully before making a formal attempt. Ready, set, go!

Flight Duration Records

Duration flights must be made indoors. This is to prevent a lucky thermal or gust of wind from giving the plane a helping hand.

You will need two independent judges to make sure the rules are enforced and to measure the flight time. You will also need someone to take a video showing the entire flight from launch to landing. Guinness won't recognize a record without the video.

Takuo Toda winding up to launch a paper airpline for a longest flight duration record attempt. Photo courtesy of Takuo Toda.



Takuo Toda casts a critical eye toward one of his planes as he checks to make sure the wings are in alignment. Photo courtesy of Takuo Toda.

You may make ten attempts, which include fouls but not flights deemed unmeasurable by the judges. This is to prevent siege assaults on the record and reduce stress on the judges.

The plane must be made of one sheet of A4 or letter size paper of less than 100 gsm weight. It may be cut, but the parts removed may not be reattached. You may use up to 25 mm by 30 mm of cellulose tape, cut or whole, to fasten folds, but for no other purpose. This rule prevents gaining an advantage by using specialized materials or designs. Everyone will be flying roughly similar origami airplanes.

The airplane is to be flown by one person, standing still on a level floor with

both feet on the ground. The launch point must be level with or lower than the landing point. This rule is intended to equalize flying conditions and neutralize handicaps.

The flight time is measured from the moment the airplane leaves the thrower's hand until it first touches the floor or any other object. If any object helps the airplane in flight, the judges will call a foul.

The time is measured with digital stopwatches to a hundredth of a second, and the two times averaged and rounded to a tenth of a second. If the judges can't agree on a time, as when it isn't clear to both whether the airplane struck an object or not, for example, the flight is considered void.

If any of the ten attempts exceeds the current record, the thrower must send signed statements from the judges, and the video, and color photographs, and as far as possible, newspaper clippings for independent corroboration, to Guinness for authentification.

Chris Edge's "White Flyer" (front) and Andy Currey's "Delta Belter" (rear) designs tied to set a record for longest duration flight in 1996. The record fell to Ken Blackburn two years later, and has been held by Takuo Toda since 2009.

Takuo Toda's unique wind-up allows him to launch his planes to dizzying heights without distorting the wings or creating excess drag. Photos courtesy of Takuo Toda.

Flight Distance Records

The Guinness rules for distance flown records are very similar to those for duration. The flights must be made indoors, and there can only be ten of them. Two independent scrutineers do the judging and measuring. The plane must be constructed from the same type of paper, with cuts and a small amount of tape allowed. But rejoining trimmed off pieces is prohibited.

The biggest difference from the duration rules is the way the plane is launched. It is thrown unaided by one person from behind a 32.8-foot (10-meter) wide line with a mark in the center. The thrower is allowed a 32.8-foot (10-meter) run up, but must not touch or cross the line until after the plane has been launched. No ramps or other aids are allowed, and the launch point may not be higher than the landing point.

The plane may not roll more than 4 times in flight. This is to prevent the use of tightly rolled paper darts that do not actually fly in a sustained and stable way. (Some contests do not require this, but if the record is for a flight, the plane should be able to fly!)

Several examples of John Collins' "Suzanne" paper airplane, ready to make history for longest distance thrown. Photo courtesy of John Collins.

Former arena football quarterback, Joe Ayoob throwing John Collins' "Suzanne" into the record books. Photo courtesy of John Collins.

The distance flown is measured in a straight line from the mark in the center of the launch line to the point where it first touches the ground or any other object. If the plane is aided by any object, the flight will either be measured to where the event occurred, or be declared a foul. Only one scrutineer is required to call a foul.

Authentication of the flight is to be made in the same way as for a duration record.

If your plane is record caliber, you will probably need several very long measuring tapes laid end to end. Draw or tape a line on the floor where the present record is, and you'll know you have a record flight when your plane goes past it.

Wingspan Records

Another interesting Guinness record is that for the paper airplane with the largest wingspan capable of flying more than 50 feet (15.2 meters). It is much more difficult than you think, because your plane needs to be bigger than a Cessna to have a chance.

Like the other records, the flight must be made indoors. There are to be two scrutineers, and ten attempts are allowed.

The plane itself must be made from paper of no more than 150 gsm in weight, which is about twice as thick as copy paper. Glue can be used to join parts and laminate paper for main structural components, but it must not cover the wing itself. No materials other than paper and glue are allowed.

The wingspan is measured before the first flight.

The plane must be flown by one person, who may use a platform up to 10 feet (3 meters) tall. The thrower is allowed a 10 foot (3 meter) run-up to the throw, and must not leave the platform before releasing the plane. The plane must fly completely past a line drawn 50 feet from the edge of the platform. If the plane is aided by any object, the flight will either be measured to where the event occurred, or be declared a foul. Only one scrutineer is required to call a foul.

Authentication of the flight is to be made in the same way as for a duration record.

An example of a very large model airplane. There needs to be a delicate balance between weight and strength at this scale. Photo courtesy of Kakamigahara Aerospace Science Museum.

PAPER AIRPLANE RECORDS

What kinds of records are there for paper airplanes? Who has them now? What do you need to do to break them? It seems there's more to getting a world record than just folding a plane and throwing it hard!

Long Flights Are Lofty Flights

How long do you think it takes for a paper airplane to fly across the room? It might seem long, but it really only takes about two seconds.

If a plane hits the far wall after two seconds in a classroom, how big a room do you need to be able to fly for the half-a-minute needed to break the record? A sports stadium, that's how big!

Most of us don't have regular access to that big a venue. So it turns out that most of the records set in recent years have been made as part of a larger event, either a national contest, or a TV show devoted to record breaking.

And how do the record breakers get such long flights? Andy Chipling, who wrote the Guinness rules for duration and distance, breaks it down this way: the design of the aircraft is 33%, skill at building it is another 33%, and throwing technique is 33% too. That leaves 1% to unknown chance and the smile of fortune! (Though, more likely, it's up to humidity.) The higher the plane starts its glide, the longer it will take to circle down to the floor. So the throw needs to be as close to vertical as possible, for maximum height. And as often as not, the best thrower gets the record.

It takes a lot of practice to get your form just right. At first the planes may crash and crumple.

But they're just paper, so don't worry—fold up another, and stick with it!

Flight Duration Records Over the Years

1975	15.0 seconds	**William Pryor,** creating the category as well as the first record
1983	16.9 seconds	**Ken Blackburn,** on November 29 with his "Old Bossy" design
1987	17.2 seconds	**Ken Blackburn,** on July 28, as part of a record challenge TV show
1994	18.8 seconds	**Ken Blackburn,** on February 17, with his "World Record Paper Airplane"
1996	20.9 seconds	**Chris Edge,** on July 28, with his "White Flyer," at the very same time as
		Andy Currey, with his "Delta Belter" design, during a national contest
1998	27.6 seconds	**Ken Blackburn,** on October 8, with the "World Record Paper Airplane"
2009	27.9 seconds	**Takuo Toda,** on April 11, with his "Sky King" design
2010	29.2 seconds	**Takuo Toda,** on December 19, with his "Zero Fighter" design

Who will be next? Will it be you?

Getting to Know the Past Record Holders

For many years, the story of the time aloft record was the story of the rivalry between two outstanding pilots: Ken Blackburn and Takuo Toda. But it isn't a big, dramatic, personal rivalry. It's more of an endless determination by two superbly talented fliers to become, and remain, the best in the world.

Their planes are very different. Time aloft planes need to have the biggest wings possible while still having enough weight in the front to climb straight up and enough stiffness to survive the throw. Blackburn uses planes that are almost square, with no nose ahead of the leading edge and small triangular wingtip rudders. Toda uses planes with a more pointed nose, a belly-button

flap under the wings, and a sturdy lock-fold holding the nose together. And they are much smaller, using only half a sheet of A4 paper. Toda's planes, first the Sky King, and then the even more specialized Zero Fighter, have caught on with young contenders around the world because they are consistent and easy to adjust.

Blackburn uses ordinary copier paper for his record planes, but Toda uses a special bagasse paper, made from sugar cane pulp, that is exceptionally light and stiff. He tried more than 200 types of paper before finding it, and when he did, he cornered the market. The magic paper is his alone.

Takuo Toda's "Zero Fighter"

Ken Blackburn's "World Record Paper Airplane"

Blackburn's strength has been the training he did. For half a year before each attempt, he would spend an hour a day, six days a week, doing weight training and squats, and then another hour folding and flying airplanes. By contrast, Toda did little more than diet. His planes and his elegant throwing form have made anything more strenuous unnecessary. Blackburn uses brute power, which his plane has to absorb; Toda's smooth throw accelerates the plane cleanly. It's the difference between big surf and a tsunami.

Toda's form

Going the Distance

More than the record for time aloft, the record for the longest distance flown gets at the very nature of what counts as flight. Is a tightly wadded ball of paper a "paper airplane?" Is a twisted screw of paper? Or how about a dart with wings folded so many times they produce no discernable lift? Where do you draw the line?

In fact, though, wads and darts of paper don't fly as far as a well-designed plane, because they can't glide to stretch out the flight after the initial speed wears off.

John Collins was sure he had a great airplane. It flew straight and far, and a little tweaking, some very stiff paper and the careful use of tape made it even better. His problem was throwing it. When he put his strength into it, the plane fluttered and crashed. So he got a talented thrower to help him. Joe Ayoob had been a football quarterback. With a bit of training, he could make smooth flights that just ducked under the rafters of the hangar they used. And it was enough: on the day of the record attempt, the design, paper and throw all came together!

Tony Felch used a very thickly folded dart with almost no wings for his flights. But they would probably not pass the "fewer than four rolls" rule in place now. Nor would the cones and twists favored by Red Bull contestants. Stephen Krieger and John Collins both used planes with quite large wings; no doubt that's the way to go now!

Distance Records Over the Years

1979	140′ 2″	**Tony Felch,** on August 9
1982	155′ 7″	**Eugene Sykes,** on February 5
1985	164′ 4″	**James Zongker,** on March 28
1985	193′ 0″	**Tony Felch,** on May 21, with his dart-like "Nemesis" design
2003	207′ 4″	**Stephen Krieger,** on September 6, with his "Avenger"

		design
2012	226′ 10″	**John Collins** and **Joe Ayoob,** on February 26**,** with Ayoob throwing Collins′ "Suzanne" design

Who will be next? Will it be you?

Stephen Krieger's "Avenger." Photo courtesy of John Collins.

John Collins' "Suzanne." Photo courtesy of John Collins.

Paper Airplanes Contests—Then and Now

If you can't capture the world record, how about winning a contest? You'll need skill, practice, a great airplane and nerves of steel. But you have all of that covered, don't you?

The first really big contest was Scientific American's Great International Paper Airplane Contest in 1967. It started as a joke, when the editors suggested that the then brand new Concorde looked like a child's paper airplane. "Maybe a contest will uncover an even more amazing design," they kidded. But readers took them seriously, and paper airplanes poured in by the thousands.

But these were early days for paper aviation, and although there were many very innovative designs, most of the designers were working in isolation, and had no idea of just how far or long a paper airplane could fly. The winners would not even be in the running these days, but the sheer variety of airplanes was a huge stimulus to designers, and gave paper airplanes a sense of gravitas they had never had before.

Next came the Second Great International Paper Airplane Contest, sponsored by the magazine *Science '86*, in 1985. The rules said nothing about the size or construction of the airplanes, and allowed scissors and glue. This time, origami airplanes were almost completely shut out of the prizes by cleverly designed profile models made of heavy card stock, mostly by Japanese competitors. The use of card, scissors, and glue make it possible to build planes with performance well beyond the capacity of any reasonable indoor venue, so most contests these days restrict planes to origami only.

Red Bull contests are now the big boy on the block. They have been held every three years since 2006, and the organizers estimate that more than 84,000 people have participated in the qualifying events. Local winners go on to national competitions, and those winners fight it out at the international finals.

The contest has three categories: Longest Distance, Longest Airtime, and Aerobatics. The distance and duration events have rules that are quite different from the Guinness rules. Most notably, cutting and taping are not allowed. The venues have been fairly small, which has limited the performance of the winners to some degree.

Most interesting is the Aerobatics category. flights are juried, because winners can't be measured objectively like time or distance, but they reward creativity and performance. So while aircraft in the other two categories all tend to look alike, the Aerobatic category is a steady source of amazing new

ideas.

Back in 2004, Burt Rutan's SpaceShipOne won the X-Prize by making two flights over 100 kilometers (62 miles) high in two weeks. These were the first private flights to space. As soon as that was done, Rutan started working to build a bigger version for Richard Branson's Virgin Galactic, which will take passengers to the edge of space. This model is based on that plane, SpaceShipTwo.

A British Airways Concorde G-BOAC. This airframe inspired the first generation of paper airplane innovators in 1967. Photo by Eduard Marmet (www.airliners.net).

A glue-and-cardstock paper airplane created by the author. This is the type of plane that shut origami planes out of the running in the Second Great International Paper Airplane Contest in 1985.

Julian Chee Yie Jian demonstrating at a Red Bull contest. Photo courtesy Red Bull / Kumail Rizvi.

The Biggest Airplanes and the Highest Flights

The records for the largest airplane and the highest flight are perhaps not as glamorous as those for time aloft and distance flown, but they are just as difficult, and require large teams of people to achieve.

The rules for the highest launch do not require the plane to be launched by hand, so remote controlled devices attached to weather balloons are now the preferred technique. The planes are released so high that the balloon is invisible from the ground, and the planes can fly surprising distances before landing, so cameras and computers are needed to verify the launch. And because the balloons fly well above the level of commercial flights, special permission is absolutely necessary.

The current record was set by David Green and a group of students as a high school project. But another flight, made in 2011 by Project Space Planes, led by Joel Veitch and with a bundle of planes designed by Andy Chipling, reached a height of 122,192 feet (37,244 meters) for an unofficial record. The planes carried memory chips, and flew immense distances from the launch site over Germany, to Canada, South Africa and even Australia, after flying as much as 10,000 miles.

Size and Altitude Records

Largest Paper Aircraft 59.74 feet (18.21 meters) on September 28, 2013	**Braunschweig Institute of Technology,** on September 28, 2013
Highest Altitude Paper Airplane Launch 114,970 feet (35,043 meters) weather balloon over Elsworth in the UK	**David Green,** on June 24, 2015, with a weather balloon over Elsworth in the UK

Who will be next? Will it be you?

The largest paper planes are now so huge they have wingspans longer than the distance they are required to fly. The limiting factors are weight and the width of the room used for the flight. As the plane becomes bigger, it requires more and heavier structure to keep it from crumpling in flight. But the plane has to be lifted and launched by one lone thrower, so the extra weight, and the inertia and drag of the huge structure, make it more and more difficult to launch. What is the limit? Why not get your friends together and find out?

More Records Waiting to be Broken

Guinness recognizes a surprising number of records for paper airplanes, and is open to creating new categories. That means you have lots of chances to set a record

besides just breaking the 30-second barrier or throwing your plane more than 227 feet (69 meters). You can challenge one of the records here, or come up with something completely different.

- **Largest paper aircraft (current record: 59.74 foot/18.21 meter wingspan) • Farthest flight by a paper aircraft (current record: 226 feet 10 inches/69.13 meters) • Longest flying paper aircraft—duration (current record: 29.2 seconds) • Most paper aircraft launched simultaneously (current record: 12,672 planes) • Most consecutive times to hit a target with a paper aircraft (current record: 13) • Most paper aircraft flown into watermelons in 1 minute (current record: 12) • Most paper aircraft made in 5 minutes (team) (current record: 4,880) • Most people making paper aircraft simultaneously (multiple venues) (current record: 803**
- **Most paper aircraft made and caught in 1 minute (team of 10) (current record: 25) • Most times to hit a target with paper aircraft in 3 minutes (team) (current record: 155) • Highest altitude paper plane launch (current record: 114,970 feet/35,043 meters)**

How about, the most paper airplanes juggled simultaneously? Or, the farthest flight of a paper airplane launched by foot?

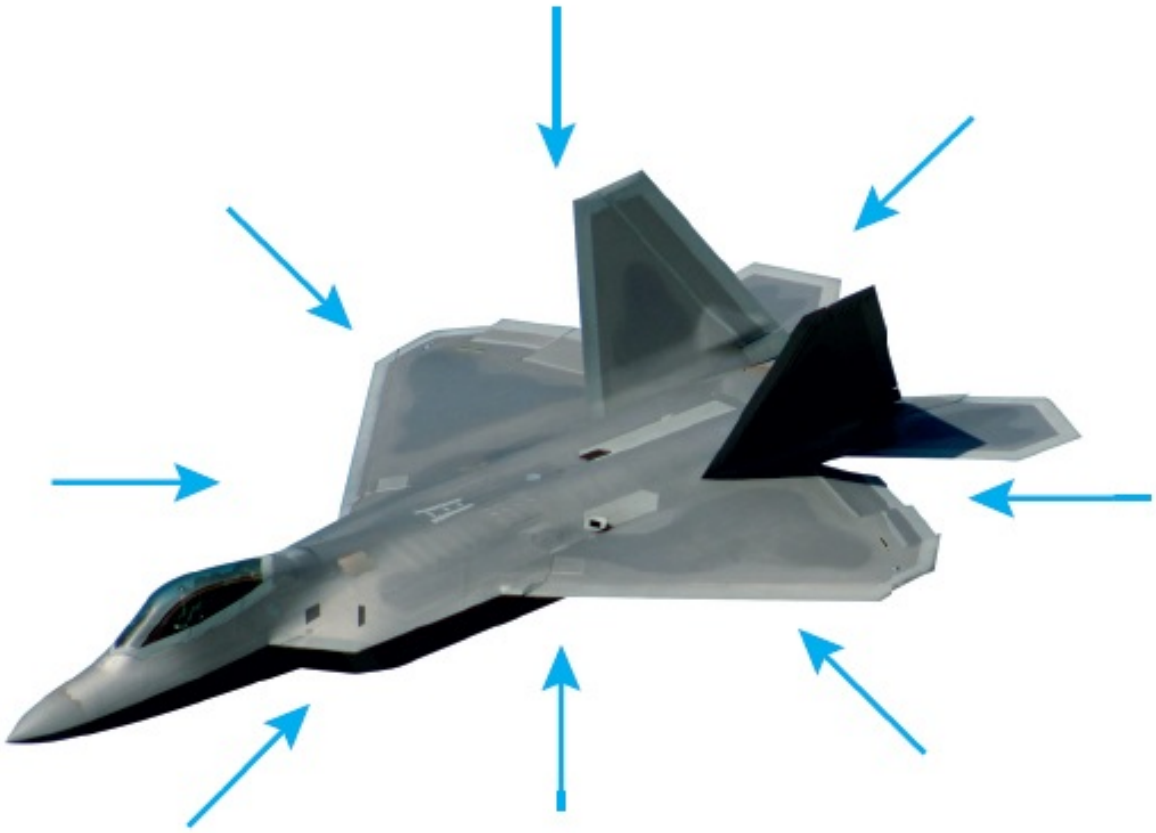
HOW AIRPLANES FLY

There are a lot of ways that things can fly. They can be lighter than air, like a party balloon, and float on the breeze. They can be picked up by the wind, like a kite, or a spider, or a dandelion seed. They can rise on a jet of hot air or gas, like a rocket. They can flap their wings, like hummingbirds and bees. They can be pushed or pulled by an engine, like a jumbo jet. Or they can glide on widespread wings, like sailplanes, eagles, and paper airplanes.

But what do we mean when we talk about flying? To be flying, an object has to stay in the air without falling down instantly. Some argue that the paper airplane that goes farthest is a tight wad of paper. But the wad isn't flying. It's falling from the moment it leaves your hand. To be flying, it has to have lift, and keep going steadily without slowing down or diving to the ground. Paper airplanes can't stay up forever, but they can glide a long way, down a long straight line. This section will tell you how those wings of paper really fly.

"Lift" is what holds flying things up. In an airplane, lift is made by the wing moving through the air. How? Let's find out!

Did you know that air is pushing on us all the time? Still air pushes from every direction equally. Our bodies push back the same amount, which is why we don't usually feel it. We can feel wind, because that's moving air, which hits one side of us and feels like a bigger push.

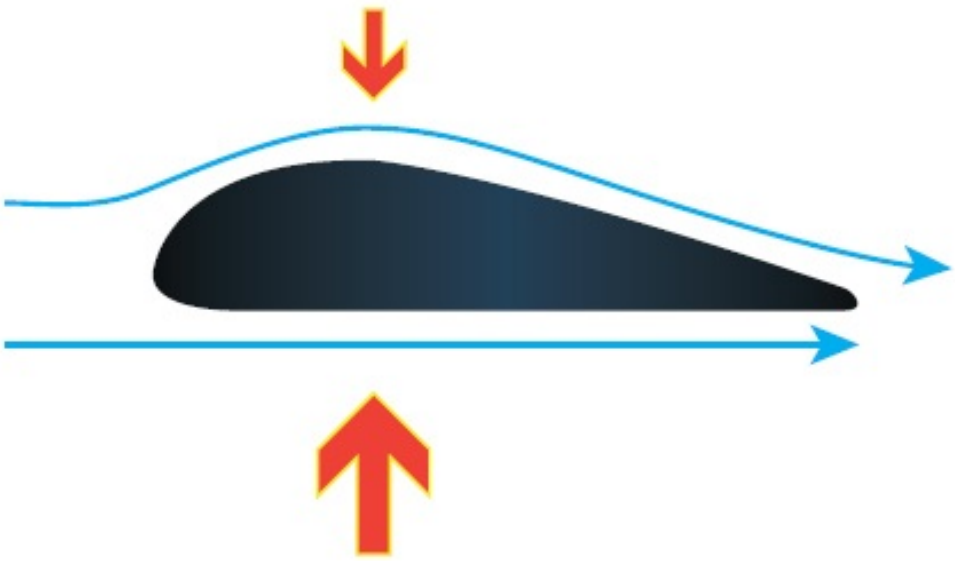


If air is pushing on both sides of the wing equally, nothing will happen. So a flat wing like a plank won't work. A shape that is curved on top and flat on the bottom is much better. It will create lift when air flows over it, because the air flows faster over the top, reducing the pressure pushing down on that surface. The greater pressure pushing on the bottom lifts the whole wing up. This kind of curve is called camber, and a cambered shape is called an airfoil.

Why does the air on the top of the wing speed up? And why does that reduce the air pressure there? It's because of three special effects: the Coanda Effect, the Kutta Condition and Bernoulli's Principle.

The Coanda Effect says that fluids (like air and water) tend to stay attached to surfaces they

flow over. This means that air follows the curve at the top of the wing. And because of the Kutta Condition, created by the sharp back edge of the airfoil, the air speeds up as it flows over the curve. In fact, the air going over the airfoil speeds up so much, it gets to the back of the wing faster than the air going under it!

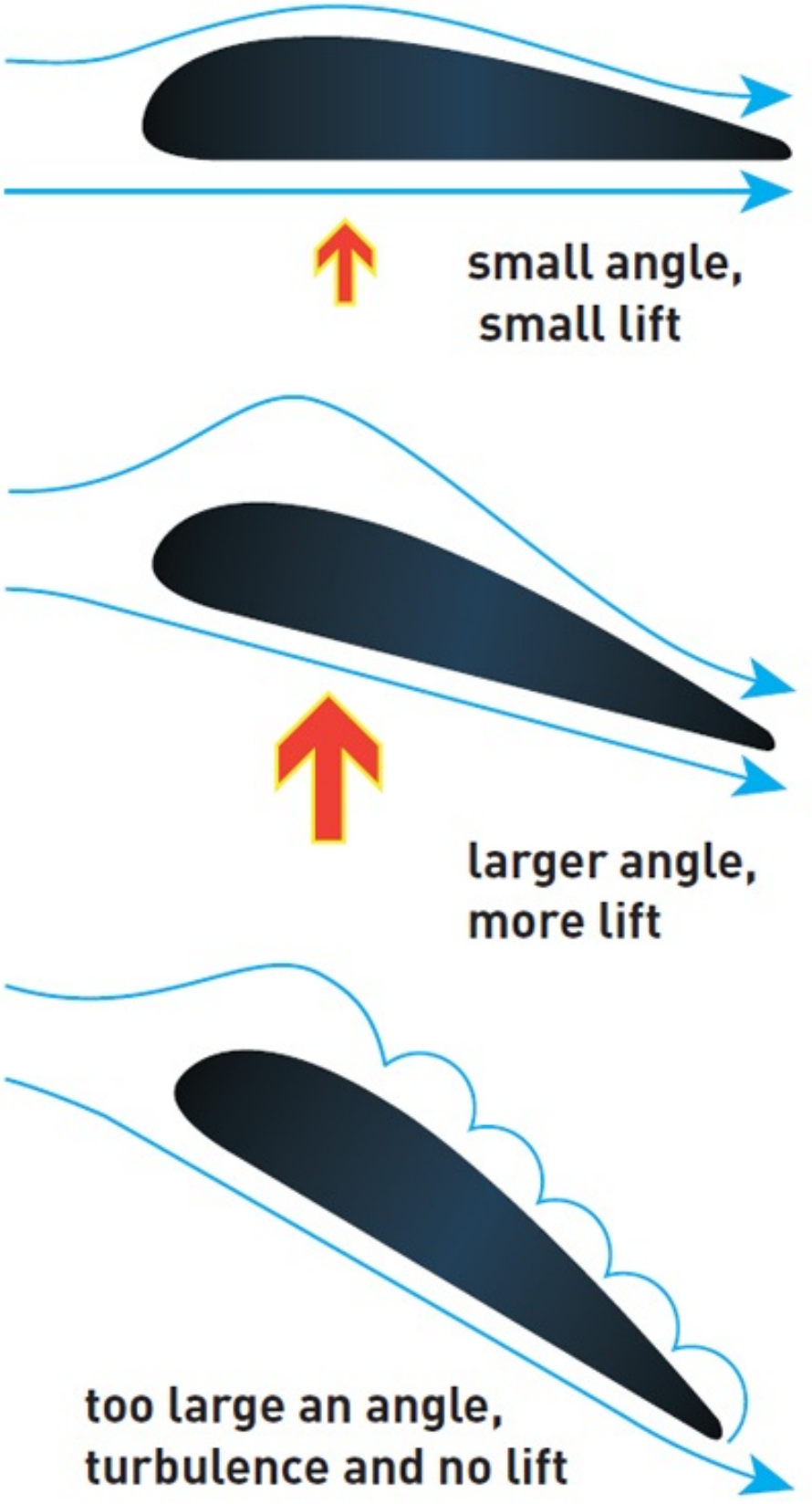


Bernoulli's Principle says that the faster a fluid flows, the less pressure it exerts. So if the air on the top of the wing is going faster, there's less pressure pushing down. That means the higher pressure on the bottom of the wing pushes it up. And lift ensues!

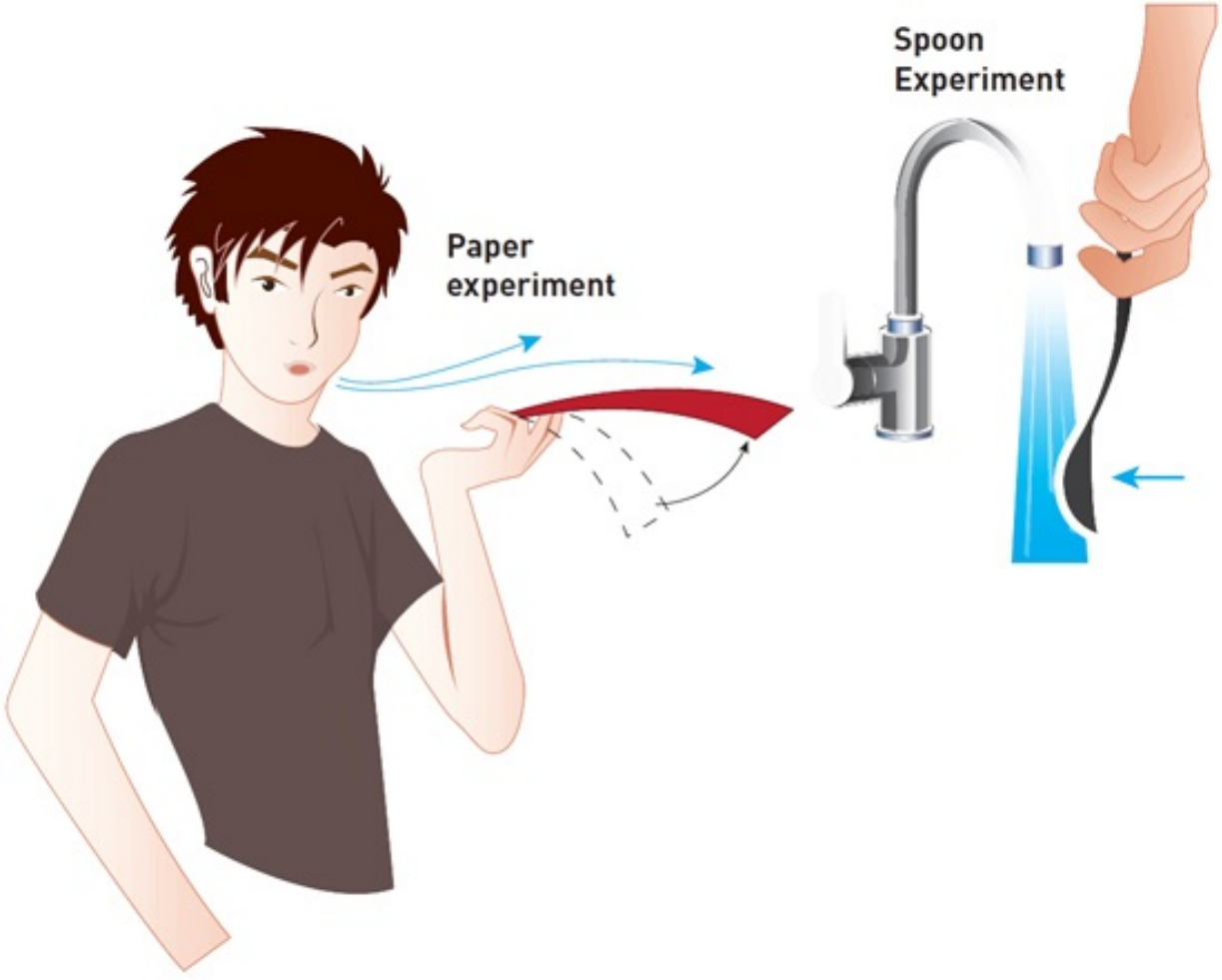
Increasing Lift

By increasing the angle of attack (the angle at which the wing hits the airflow) you can increase the amount of lift. The greater angle in effect increases the curve of the wing, so air goes over it faster, and air striking the bottom creates more direct pressure (like a kite). The bigger the angle, the more lift. But if the angle becomes too big, the Coanda Effect stops, and the air comes unstuck and gets turbulent. If that happens, the wing stops making lift and stalls. In other words, it stops flying.

More speed also means more lift. However, lift creates drag, which holds the airplane back. And drag increases much faster than the speed. When the airplane doubles its speed, the drag created by the wing quadruples! More and more power is needed to go faster, in spite of the lift.


small angle,
small lift
larger angle,
more lift
too large an angle,
turbulence and no lift

Try These Experiments!



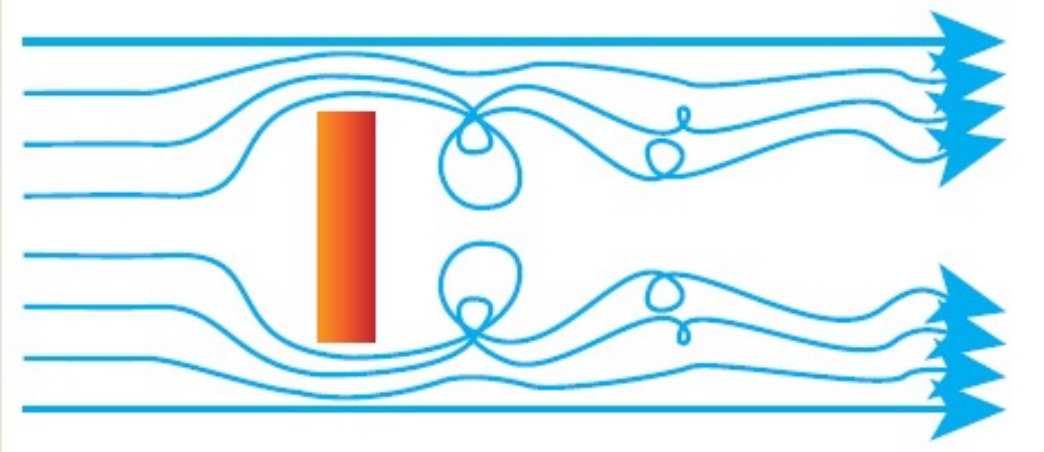
Here are two experiments you can try. First, blow over the top of a drooping sheet of paper. The paper will rise up and stand out straight, supported by the greater pressure of the still air under it. Next, try touching a steady flow of tap water with the bottom of a spoon. You'd expect the spoon to be pushed away, but in fact it is pulled into the flow. That's because the speed of the water reduces the pressure on the bottom of the spoon, and air on the other side pushes it into the flow.

Why Is Streamlining Important?

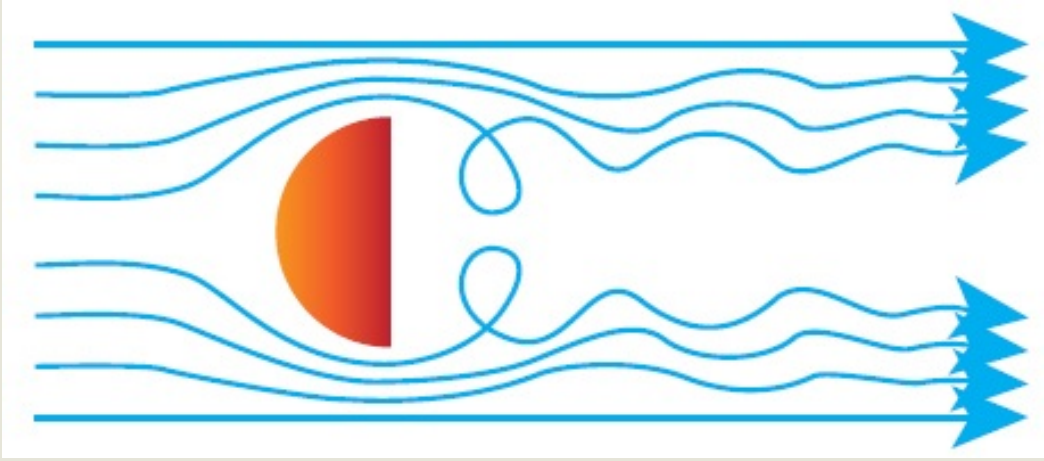
It's important for airplanes to be streamlined. They have to be smooth and

sleek to slip through the air easily. That's why sleek looking airplanes fly fast, and why fast airplanes look so sleek. Wings and airfoils need to be streamlined too.

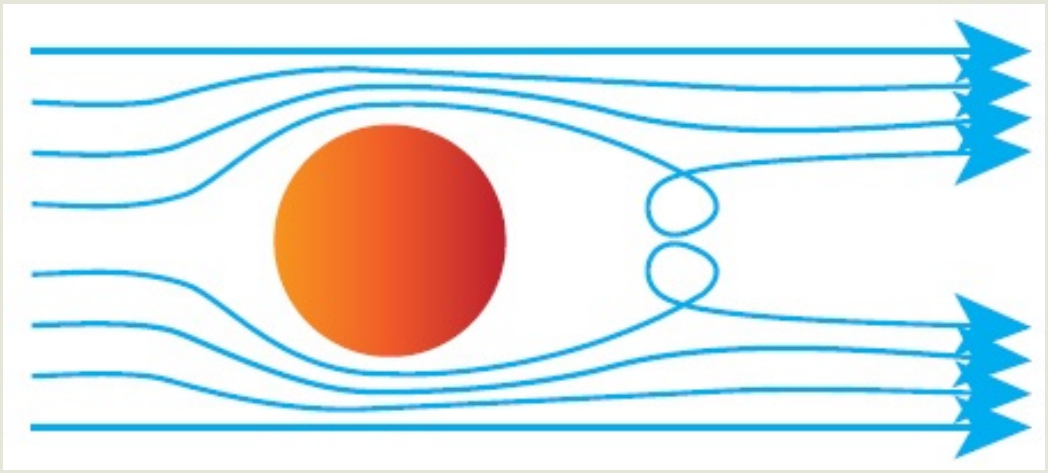
The more streamlined a wing is, the more easily air can move around it. A blunt plate is the worst. It just about stops the air, and the flow behind it is turbulent and messy. A half circle also makes turbulence, because the air can't join up neatly behind it. Round is better, and flat is most streamlined of all. But remember, flat wings don't make much lift. So the best wing shape is the one with the least drag for the most lift. In origami airplanes, that is a thin wing with several layers at the front. Too many layers of paper folded up at the front make the wing draggy. Air can't go around it smoothly. A thinner (or more sharply creased) wing is much better. By the way, putting thick folds on the top side of the wing doesn't usually work very well either!



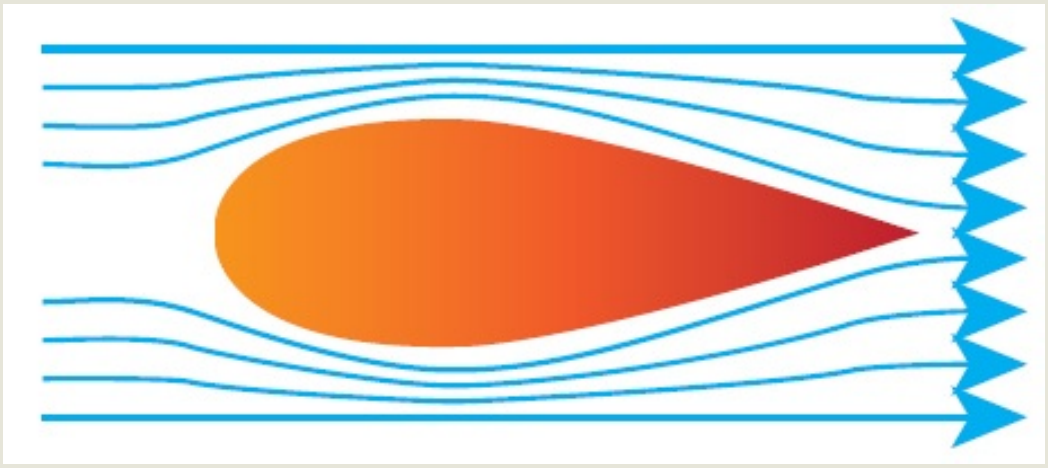
A blunt plate creates only turbulence



A half-round form is more streamlined

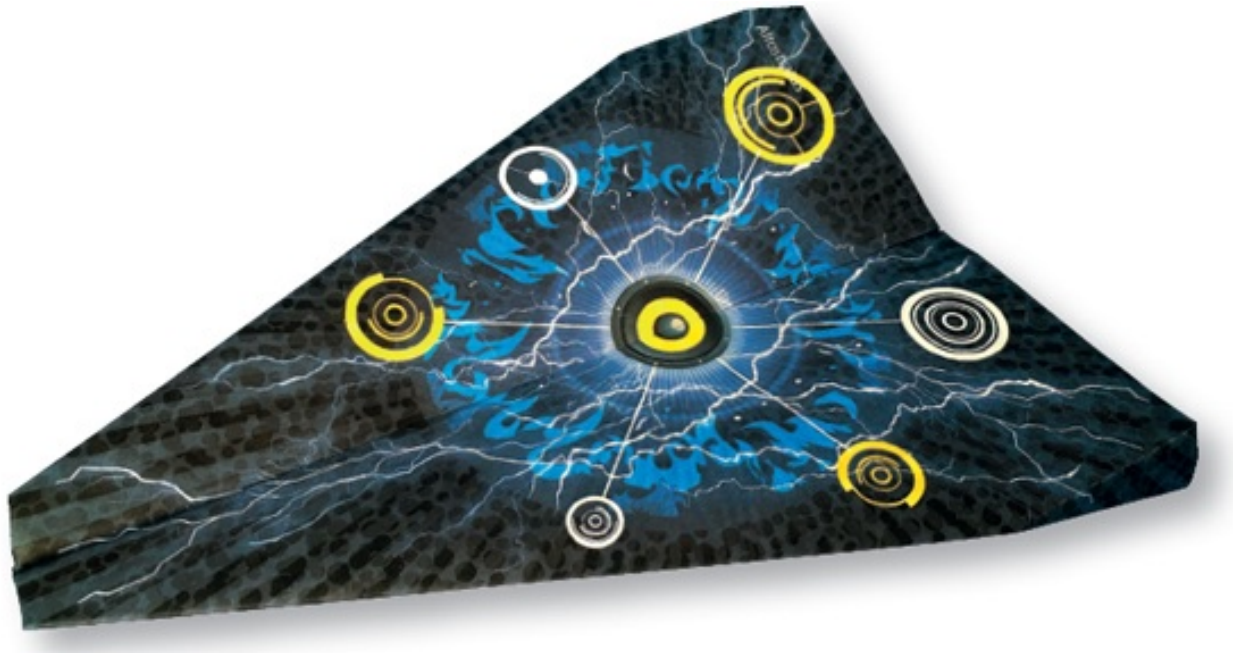


Round is better still



The classic streamlined wing shape

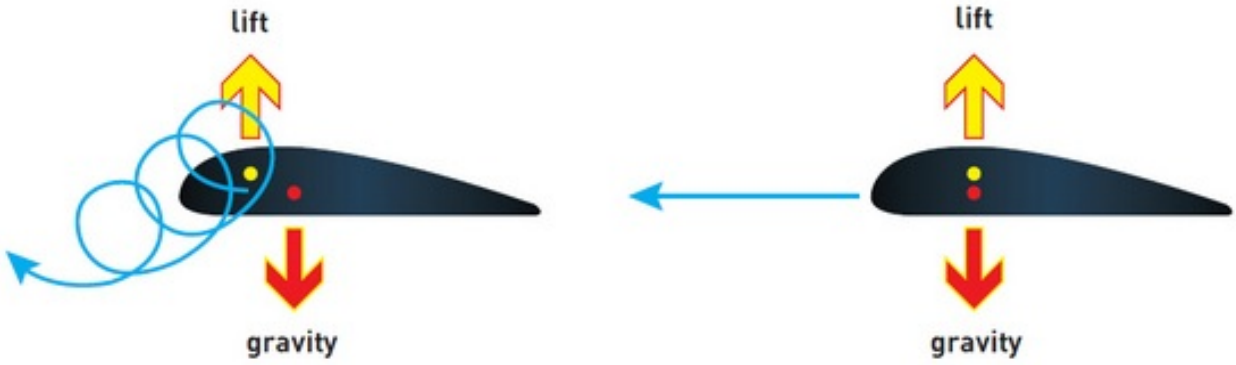
Flat is the most streamlined of all, but it creates no lift

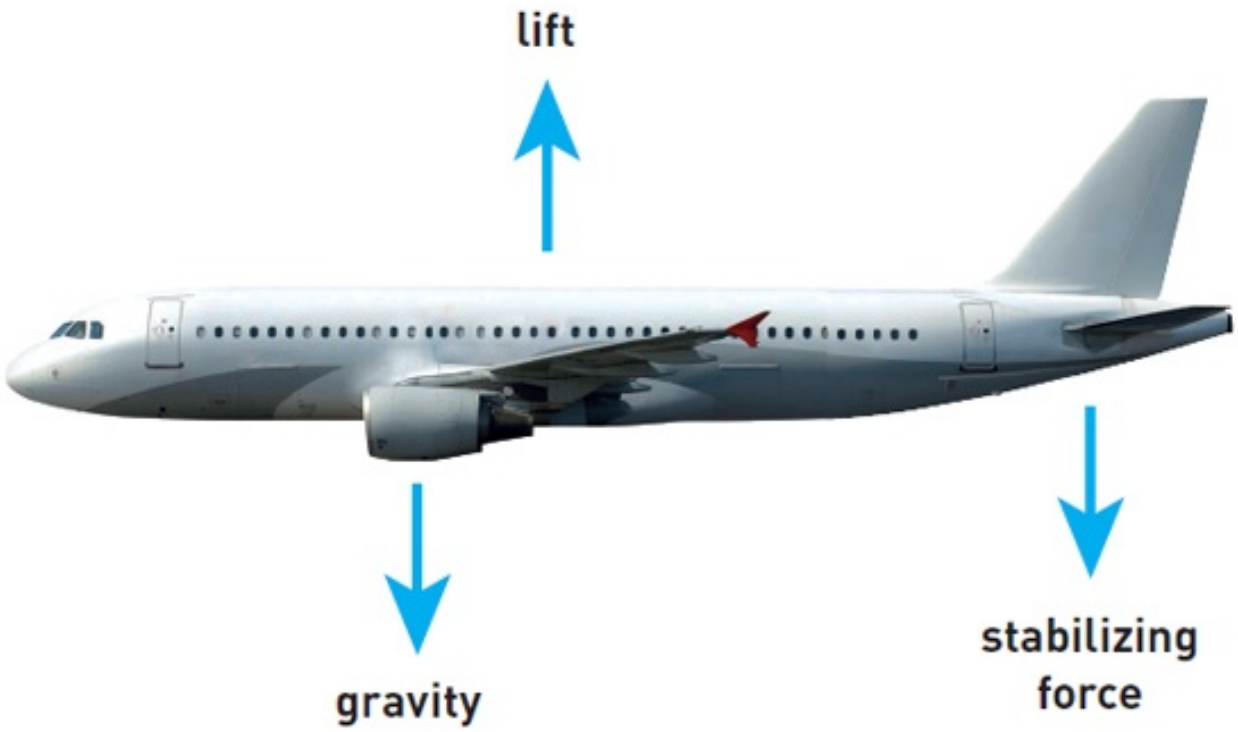


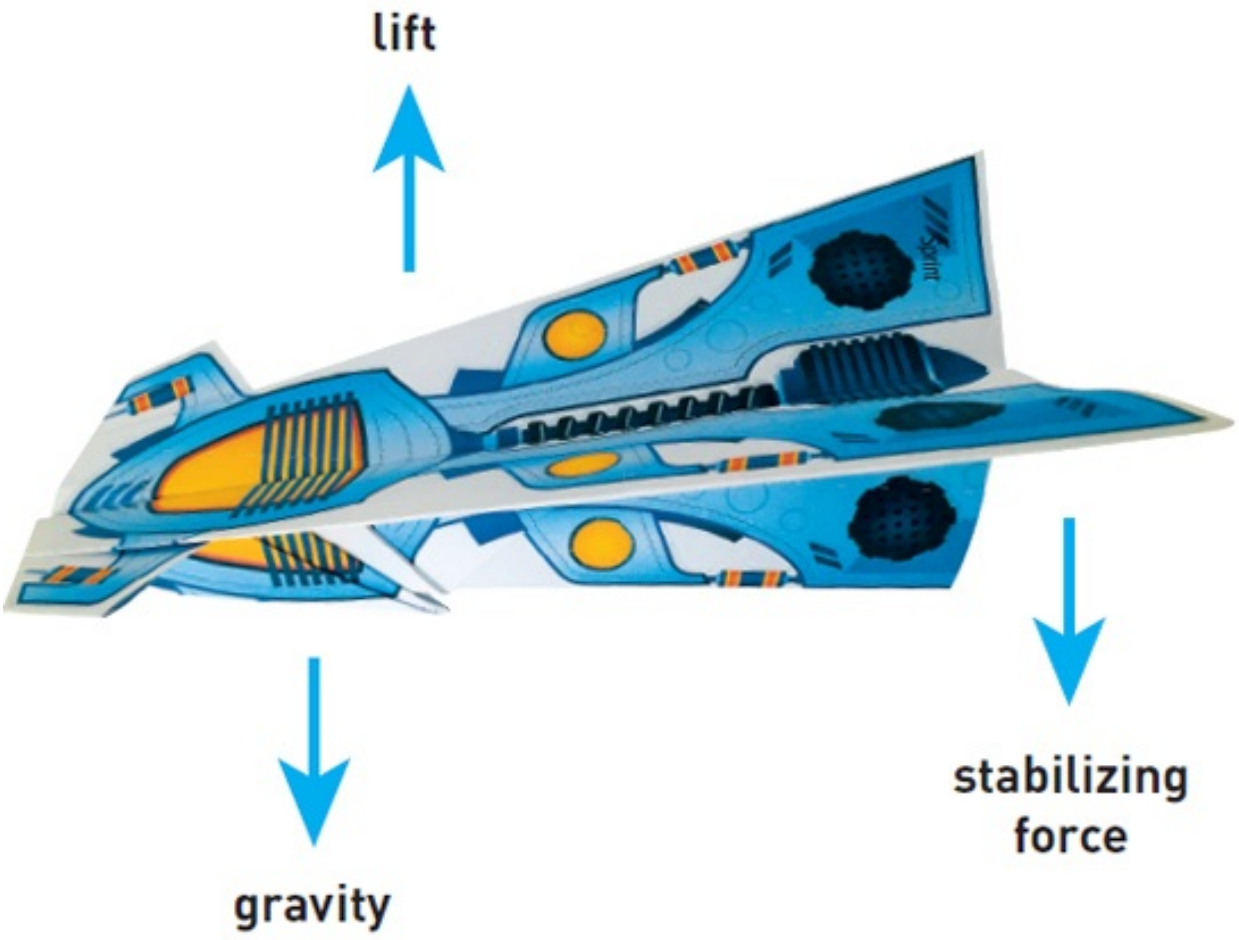
The Altostratus (page 46) boasts fantastic streamlining to reduce drag, and sufficient airfoil surface area to create impressive lift.

How to Balance Your Planes

No matter how amazing a plane looks, it won't fly unless it is balanced. Here's why!




lift
gravity
stabilizing force



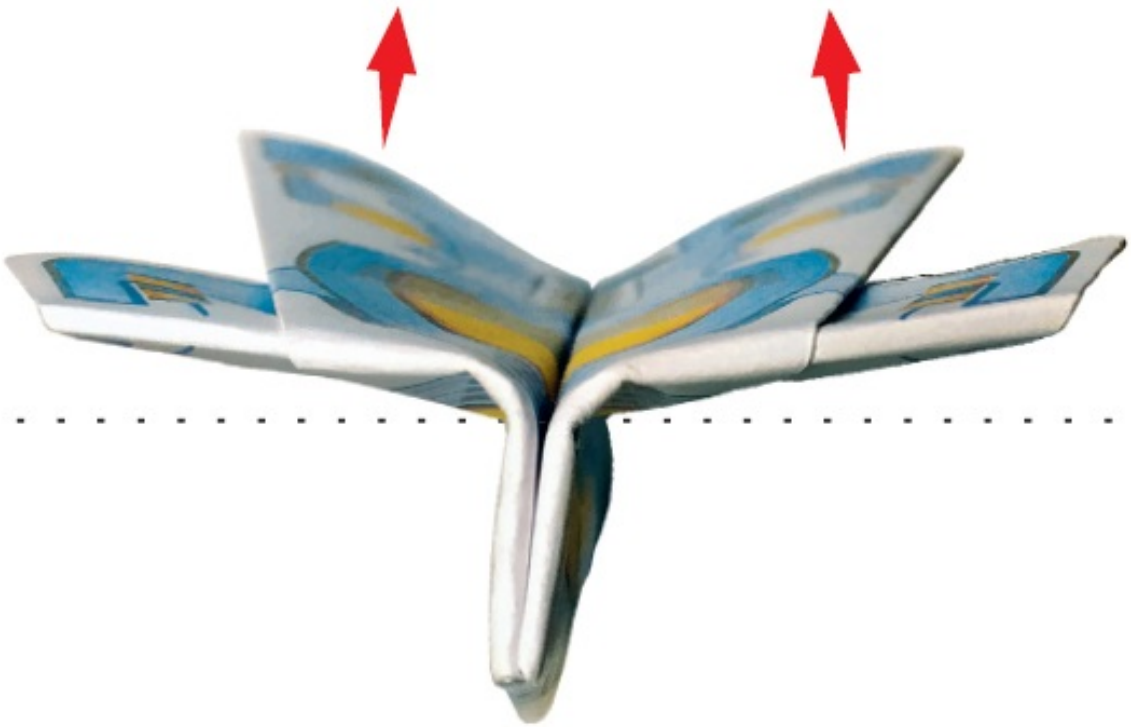
Say you have a plane which is just a wing and nothing else. The center of gravity, the place where it balances, is just about in the middle of the wing. But, depending on the shape of the airfoil, the center of lift, or place where the lift pulls it up, is a quarter or a third from the front edge. So what happens? The front edge pops up, and the wing twirls around and around. If you add some weight to the front of the wing so that the centers of lift and gravity are in the same place, the wing will balance and fly straight!

If the two centers line up exactly, though, gusts of wind and changes in speed and angle of attack would soon put it out of balance again. To deal with this, real planes usually have the center of gravity slightly ahead of the center of lift. That makes the plane want to dive, so the back of the tailplane is tilted up slightly to make a stabilizing force that pushes down. This triangle of forces holds it steady through gusts and speed changes. Most paper airplanes don't have a separate tail, but turning up the back edge of the wing has the same effect.

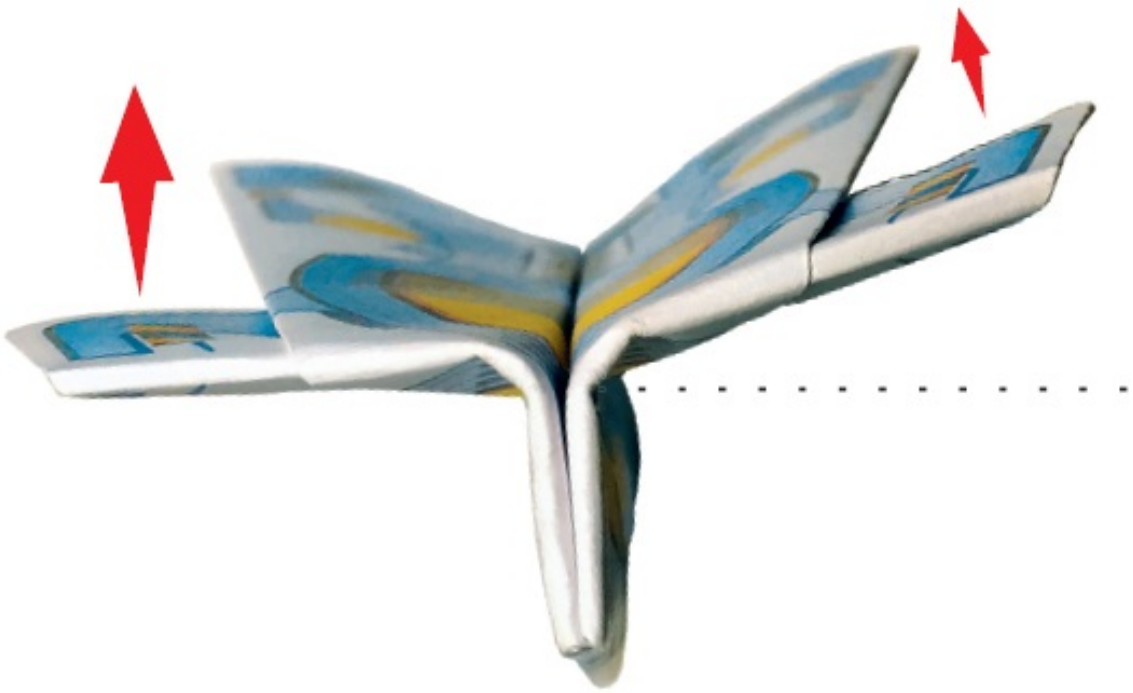
Planes have to be stable in more ways than just the balance of the wing, because there's no one flying the plane once it leaves your hand. There's no pilot, and no remote controls. So it has to be able to deal with gusts of wind and correct rolls, dives and turns on its own. It needs to be stable!

A fin or vertical stabilizer is needed to keep the plane going straight. It doesn't have to be a rudder. It could be turned-up wingtips, or a big section of fuselage at the back of the plane. But it does need to be big enough to act like a windvane and keep the plane's nose pointed straight ahead. Too small a vertical stabilizer, and the plane will spin and crash.

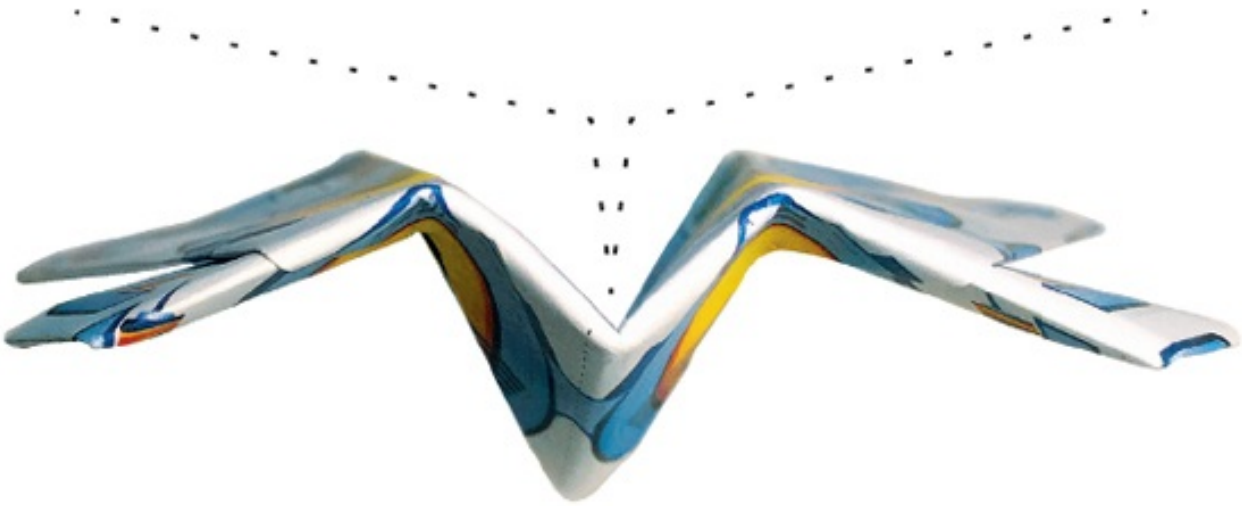
The V-shaped upturn of the wings you see when you look at the plane from the front is called *dihedral*. It helps keep the plane level. Because lift pulls at right angles to each wing, dihedral makes it seem as if the plane is hanging from two strings tied together. When the plane banks, the lift created by the level wing is greater than that of the banked wing. This straightens the whole plane until the lift is equal again. In the case of origami planes, you have to angle the wings enough so that there is dihedral even after you let go and the plane relaxes and opens out!



When the plane is level both wings create the same lift.



When banking, one wing creates more lift, which pulls it up to match the other.



The plane relaxes and opens out when it leaves your hand, so add lots of dihedral.

Use the Four Forces!

There are four main forces working on airplanes when they fly: lift, gravity, thrust and drag. Lift overcomes gravity, which is the force trying to pull the

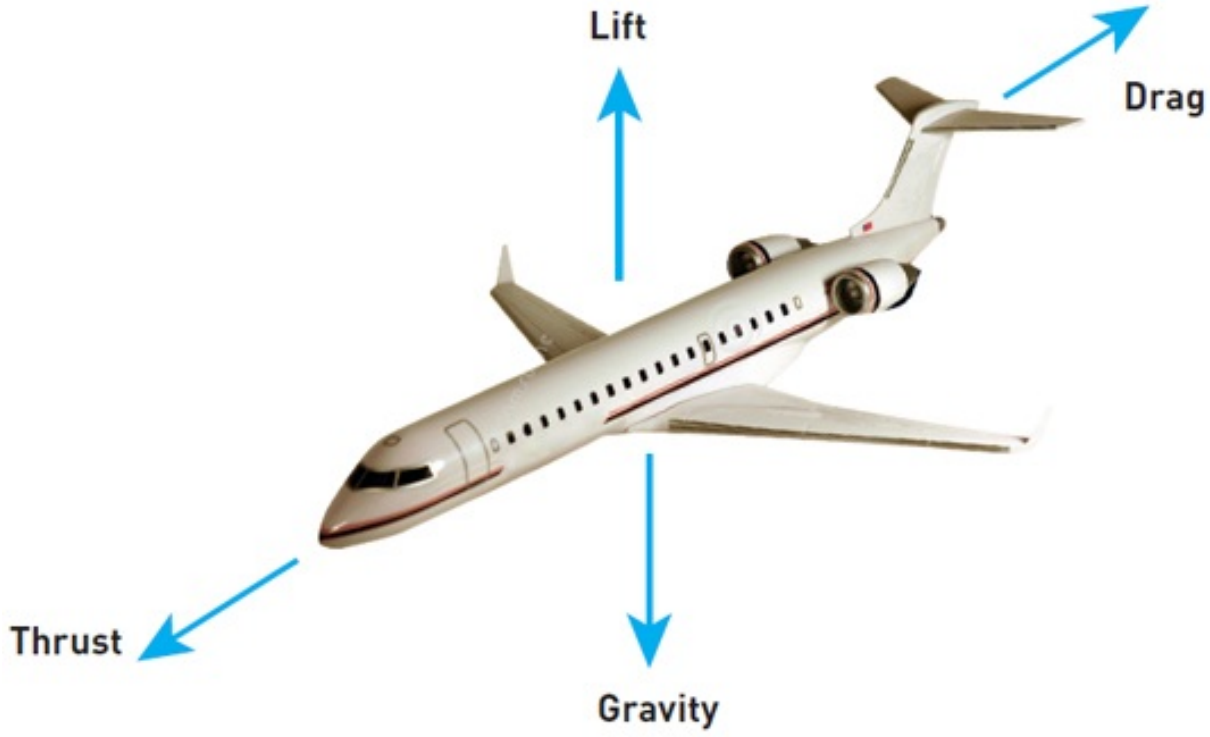
plane down to the ground. And thrust is the propulsive force that keeps the wing moving through the air; it works against drag.

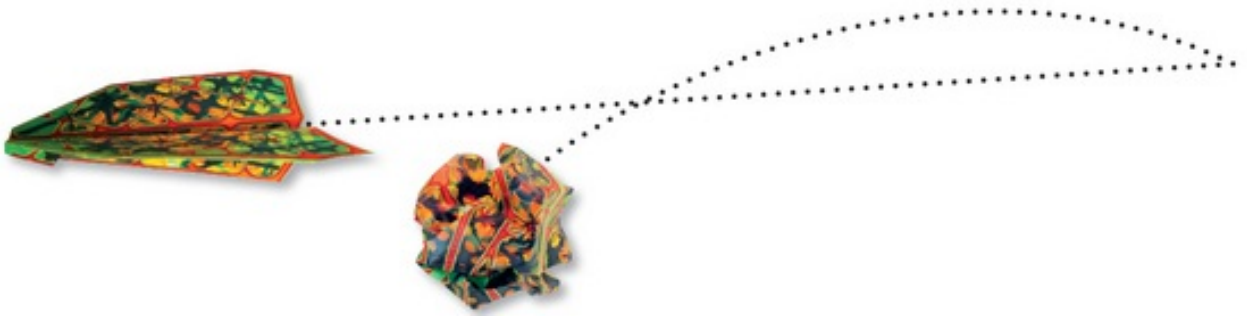
Throw a paper airplane, and your arm provides the thrust. In a real airplane, a propeller pulls it, or a jet engine pushes it. As long as the plane is sleek and streamlined, there isn't so much drag that the plane can't keep going forward. But drag also keeps it from going faster and faster, because drag gets much stronger as the speed goes up.

What about gravity? It will always pull the plane down, no matter how sleek or fast it is. Flight is always a struggle against gravity.

But what if there were no gravity? Well, the plane wouldn't fly. Why not? Because without gravity to balance the lift, the plane would just drift upwards instead of going straight, and the controls would be unable to turn the plane.

Gravity is needed for balance!

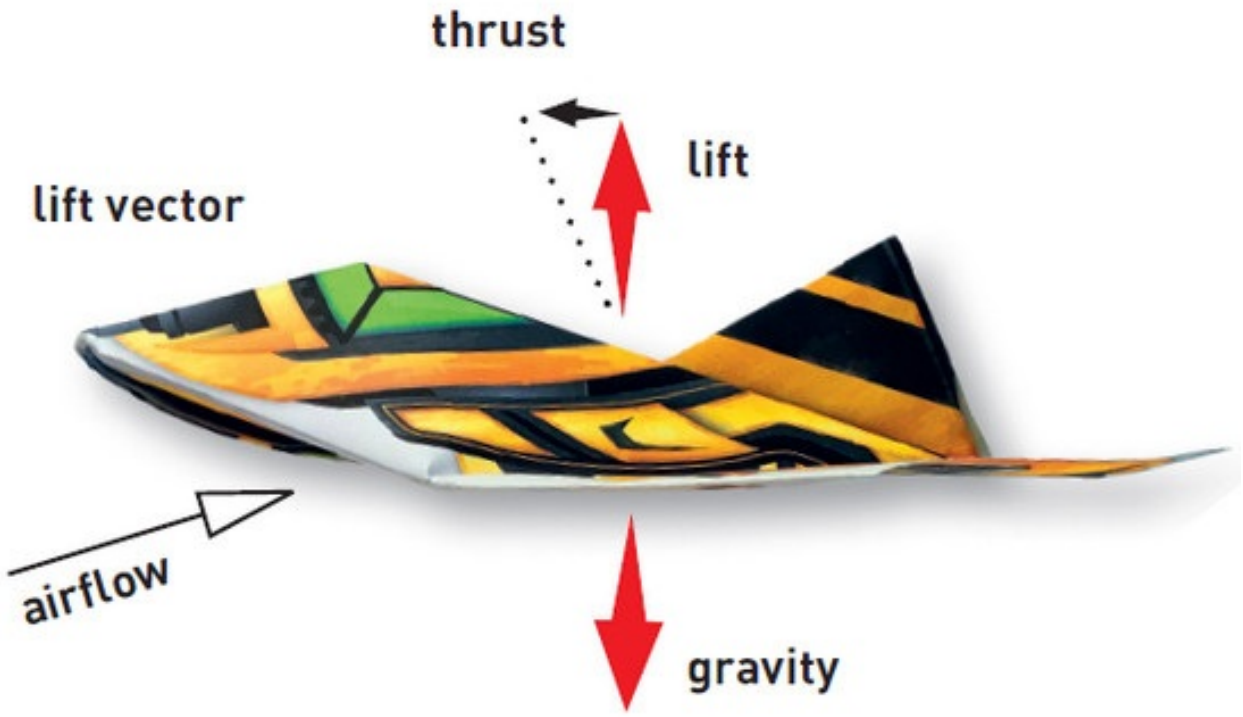




Wait a minute! What makes a paper airplane keep going? Crumple a piece of paper into a ball and throw it, and it curves right down to the ground. But a paper airplane keeps going forward in a more or less straight line, not falling and not slowing down. However far you can throw that ball, you can throw a paper airplane much farther. How come?

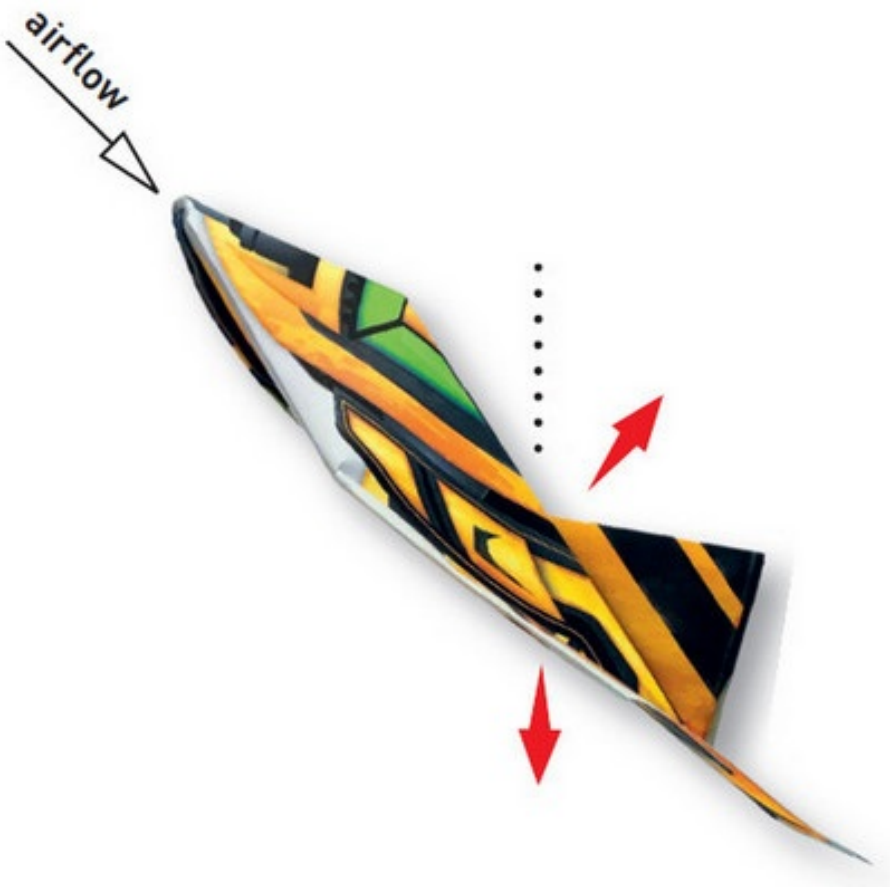
It's because lift works a little differently from gravity. Gravity always pulls straight down toward the center of the Earth, but lift pulls up at right angles to the flow of air. When you first throw your plane, it's heading straight ahead or maybe a little up, fast enough to meet the air head on. But then drag slows the plane down until it settles into a steady glide. The glide path is a long sloping line that meets the ground some distance away. The airplane looks like it's still going straight, but it's actually sliding down that sloping line, with the air hitting it from below the nose.

Because the lift pulls 90 degrees to the airflow, and the airflow is angled up, the lift is tilted forward. So, the lift is divided into two parts. One part holds the plane up against gravity, and one part acts like thrust and pulls the plane forward. As long as the thrust balances drag, the speed will stay constant and the plane will keep gliding steadily until it hits the ground.



When gliding, the airflow is angled up, and lift is tilted forward. With balanced thrust and drag, speed will stay constant as the plane glides to the ground.

In fast level flight, lift and gravity are in balance, so the plane flies straight until drag slows it down.



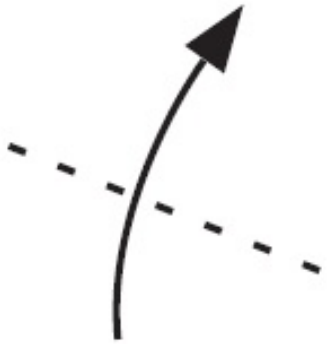
When climbing, lift pulls back as well as up, so the plane slows down.

When diving, the lift pulls forward as well as up. The forward force is just enough to balance drag.

PAPER AIRPLANE FOLDING TECHNIQUES

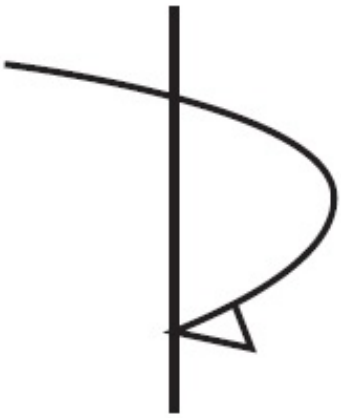
All of these planes are easy to fold, once you know how to read the instructions. I've drawn them with some symbols that are standard in all origami books, plus one or two of my own.

Here's what the arrows mean:



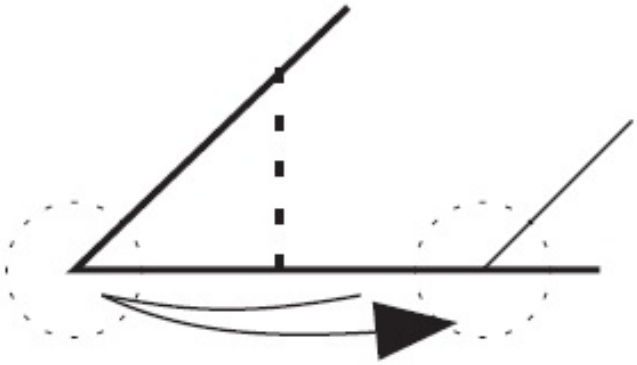
Fold this way

Fold and reopen

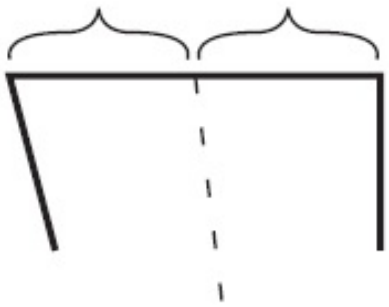


Fold around behind

Flip the whole plane over

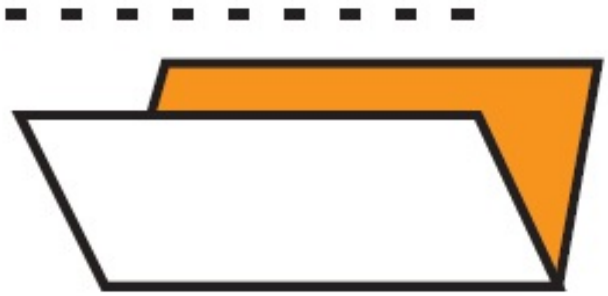


The centers of circles show what points or edges to bring together when folding.

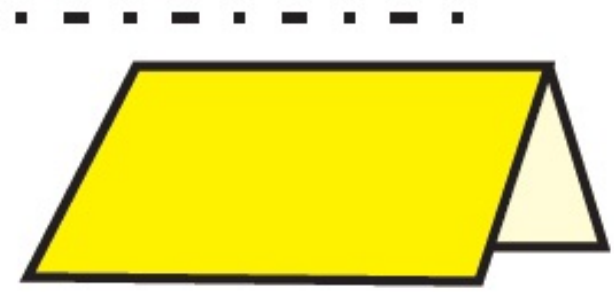


Bracket marks indicate things of the same width, such as when you fold halfway along an edge.

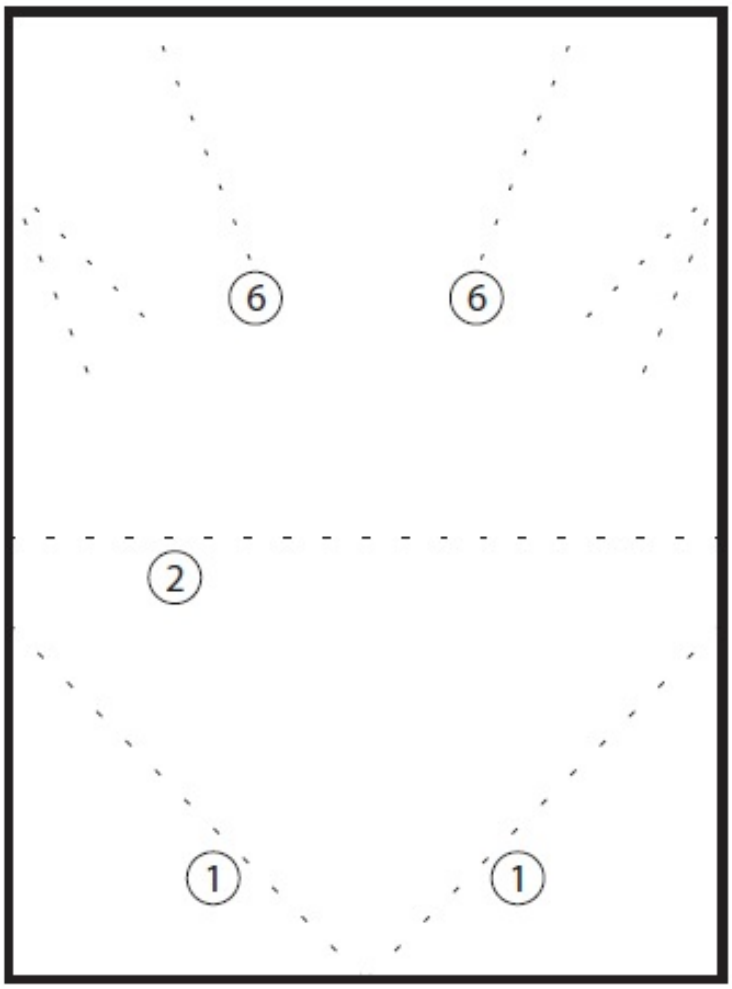
There are only two ways to fold paper: mountain folds and valley folds. For valley folds, you fold the paper towards you. For mountain folds, you fold it away. Most of the folds in this book are valley folds.



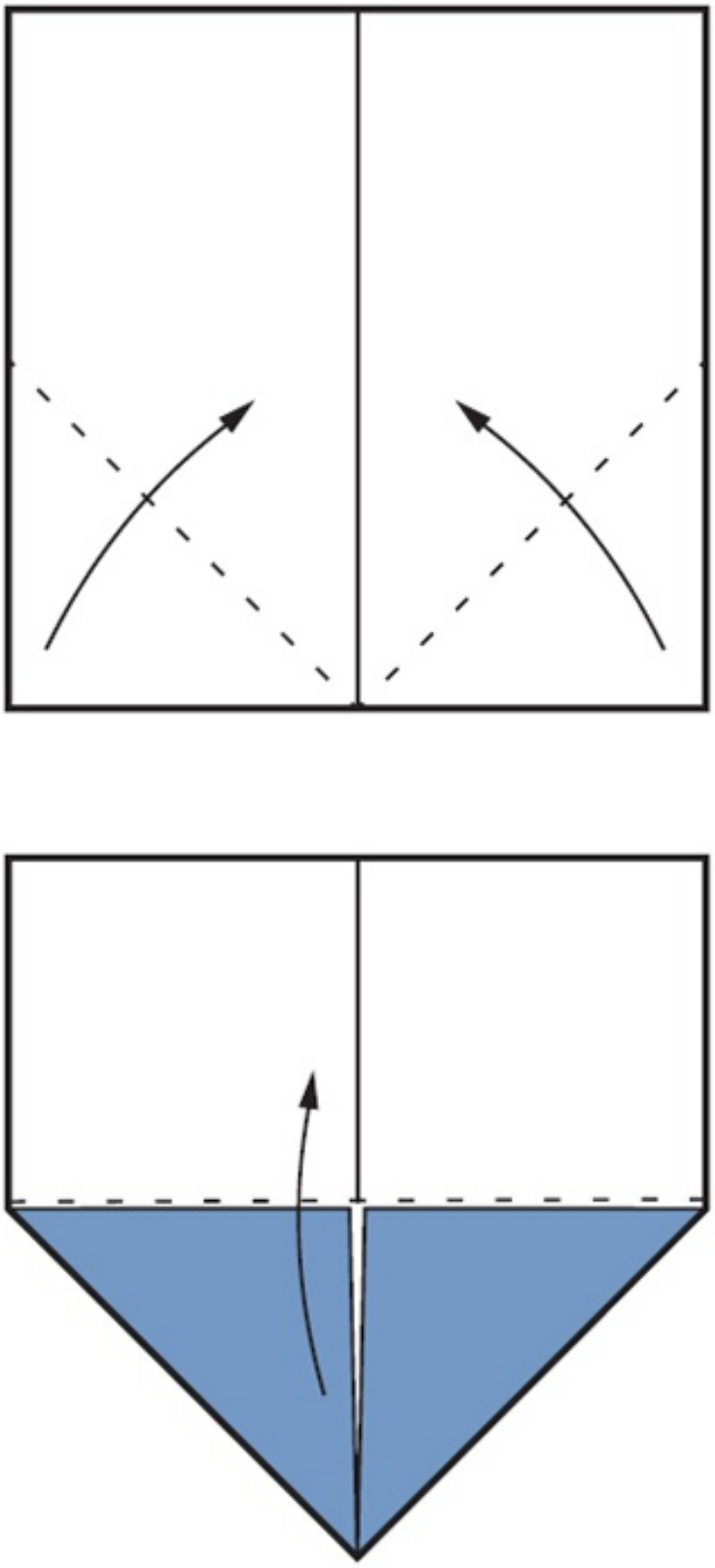
This is a valley fold; it looks a bit like a valley.



And this is a mountain fold.



To make it really easy, the origami paper in this kit already has the folding lines printed on the front and back, so every fold is a valley fold! Just follow the numbers.



Most planes start with the paper face down. The drawings show the front of

the paper in dark colors, and the back in lighter colors.

Folding is a lot easier if you do it away from you. Line up the edges or corners carefully, double check, and then crease the paper. The best way is to start from the middle, and crease first to the left, then to the right.

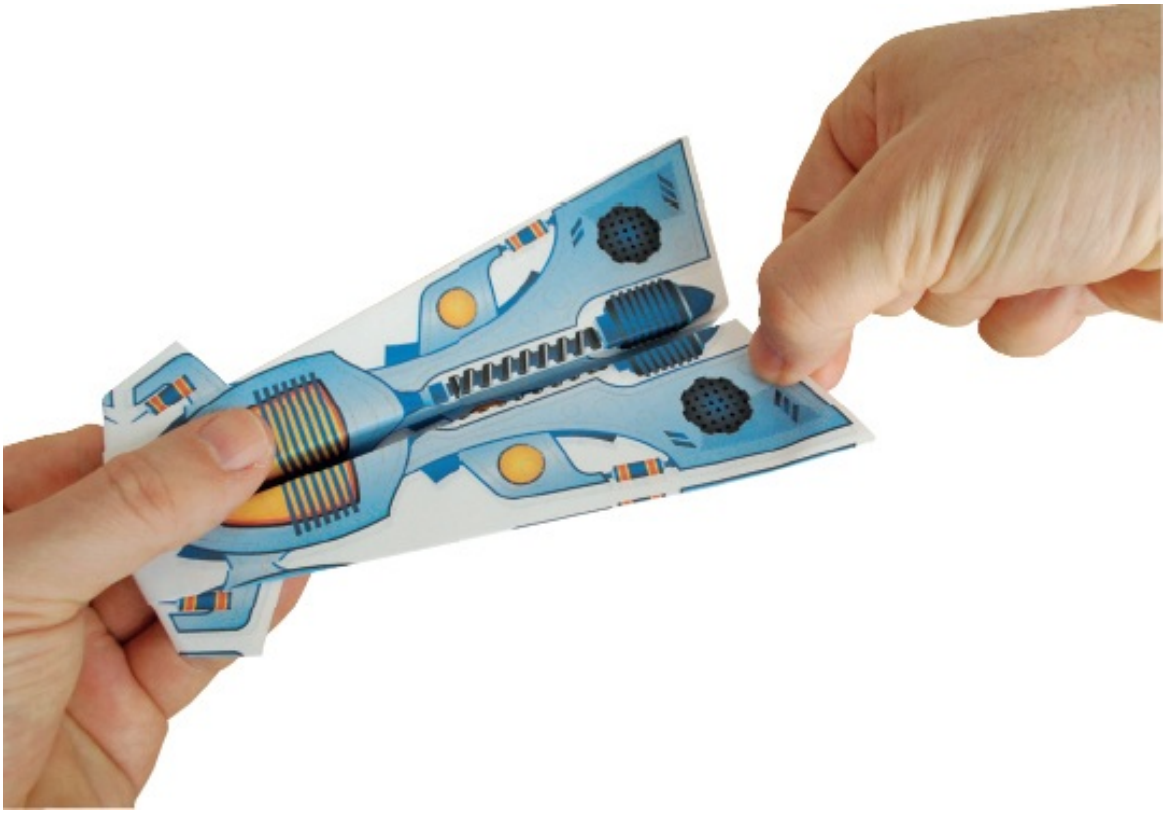
Finally, burnish the fold to make it really sharp. You can run your thumbnail along the crease, or use a tool like a pen cap.

Most of the planes need a final tweak to really fly well. They will dive until you bend up the back edge of the wing slightly. Bending the wing keeps the nose up and lets the plane float on the air. But too much, and it will stall and crash. Add and subtract until the plane flies just right.

Whenever possible, fold the paper away from yourself.

Your folds will be more accurate if you crease folds from the middle outward.

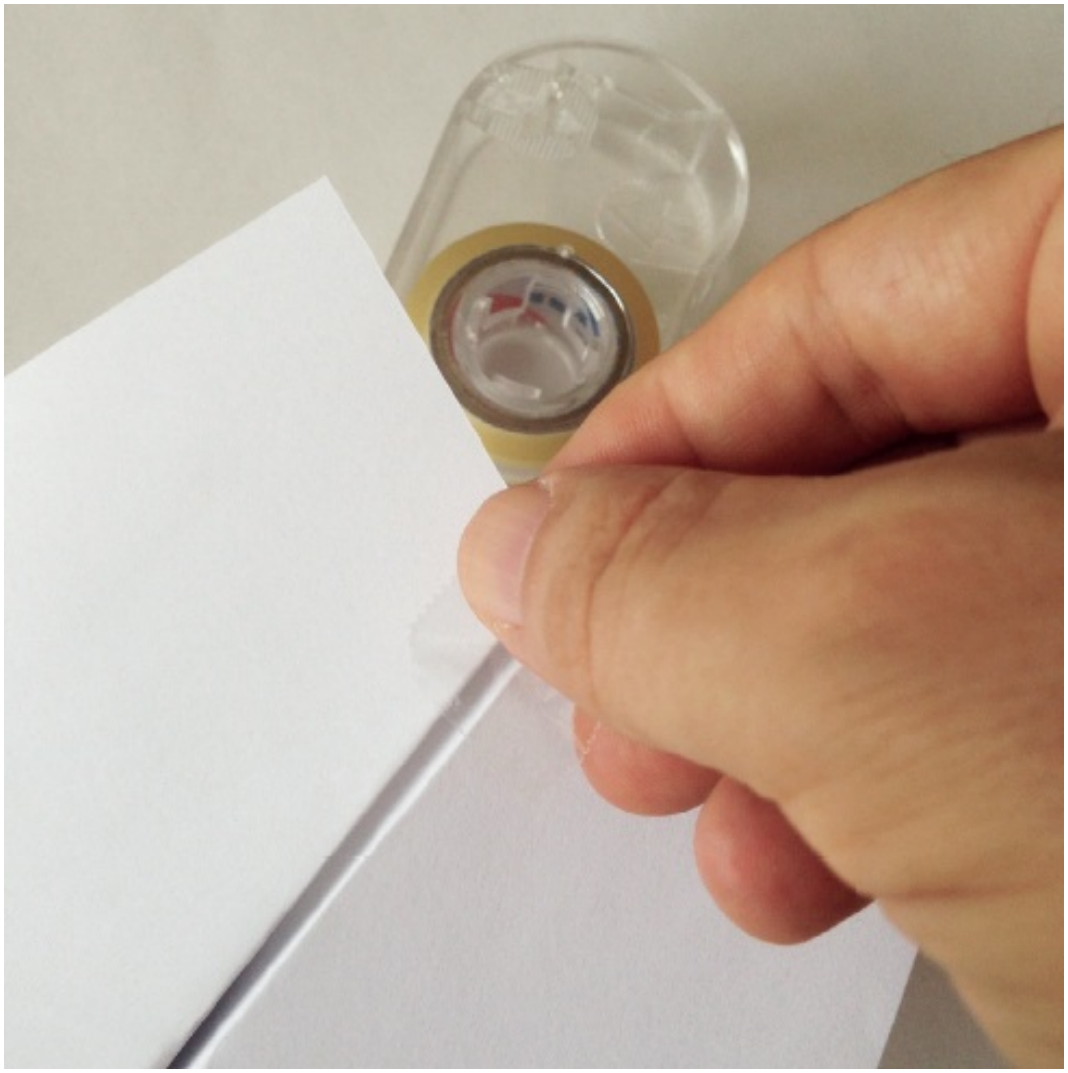
When you are sure the fold is okay, burnish it with your thumbnail to make the crease sharp.



The last step for each plane is to bend up the rear edge of the wings slightly for stability.

What About Tape, Glue and Staples?

Should you use tape, glue and staples? Origami purists say no. But the Guinness world record rules allow a small amount of tape, and some contests permit it, so I think that counts as a yes! Glue and staples are against the "rules," but that doesn't mean you can't use them on planes you make just for yourself!



Using a Little Tape Makes a Big Difference

If you do use tape, just a little bit to hold the wings or tail in place is enough. You can see the difference a tiny piece can make! When you tape the plane together like this, it will fly a lot faster and farther, but the trim will be different, so you might have to turn up the back of the wings a lot to keep it from crashing.

Can I Cut the Paper?

The plane designs provided in this kit don't require any cutting, but if you decide to start designing competitive planes of your own (see page29) you may wonder; is it okay to cut the paper? Again, "origami people" usually say no. Origami airplanes generally use one piece of uncut paper. However, the Guinness world record rules allow the paper to be cut, but the parts removed may not be reattached. If you can make an amazing plane just by folding the paper, that's great. But if you're playing on your own—or preparing to break a record—there's nothing wrong with a little cutting. See what happens. Your

plane will be great!

TEST FLYING YOUR PLANES

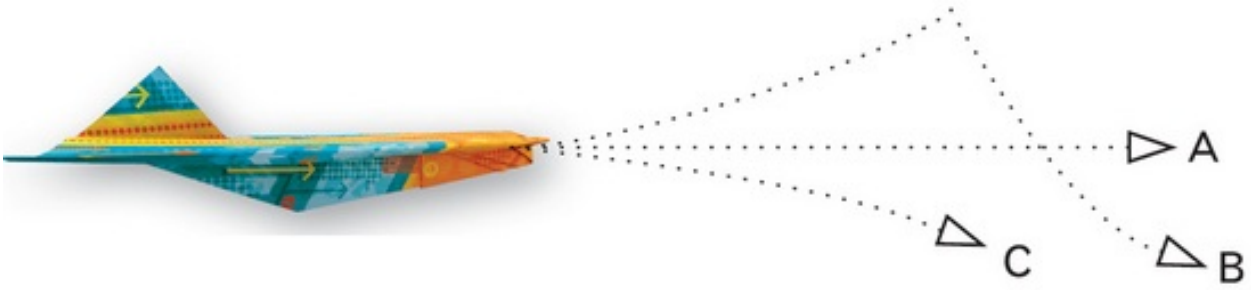
Your plane won't fly well unless it's straight. Hold it at arm's length and check. If it's out of alignment, carefully tweak the wings and tail until everything is straight and flat.

Test fly the plane by tossing it firmly straight forward and watching how it flies. If it stalls, dives or turns, adjust it as shown on the following page and test fly it again, until it glides gently.

Remember, paper airplanes are made from paper, so they bend in crash landings, and warp in sticky weather. You will have to tweak them again from time to time. If they stop flying well, check that they are straight, test fly them again, and they'll go back to being great!

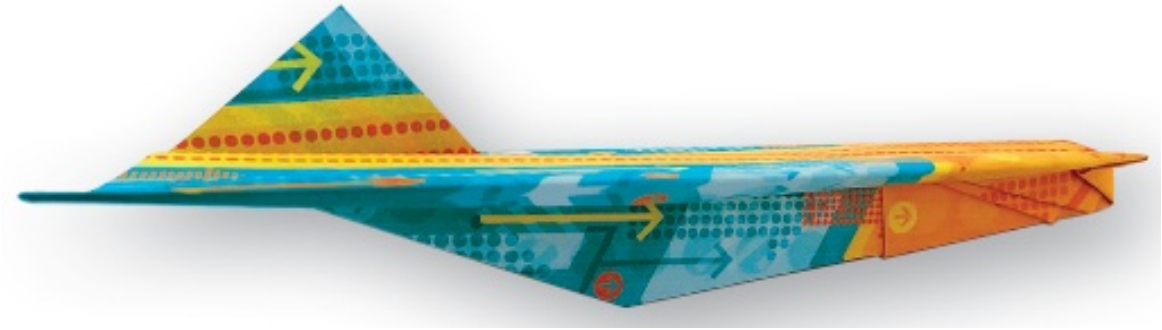
If your plane is out of alignment, make minor adjustments to change it from this...

...to this.



If your plane stalls or dives, adjust it until it glides straight, as in pattern A.

A



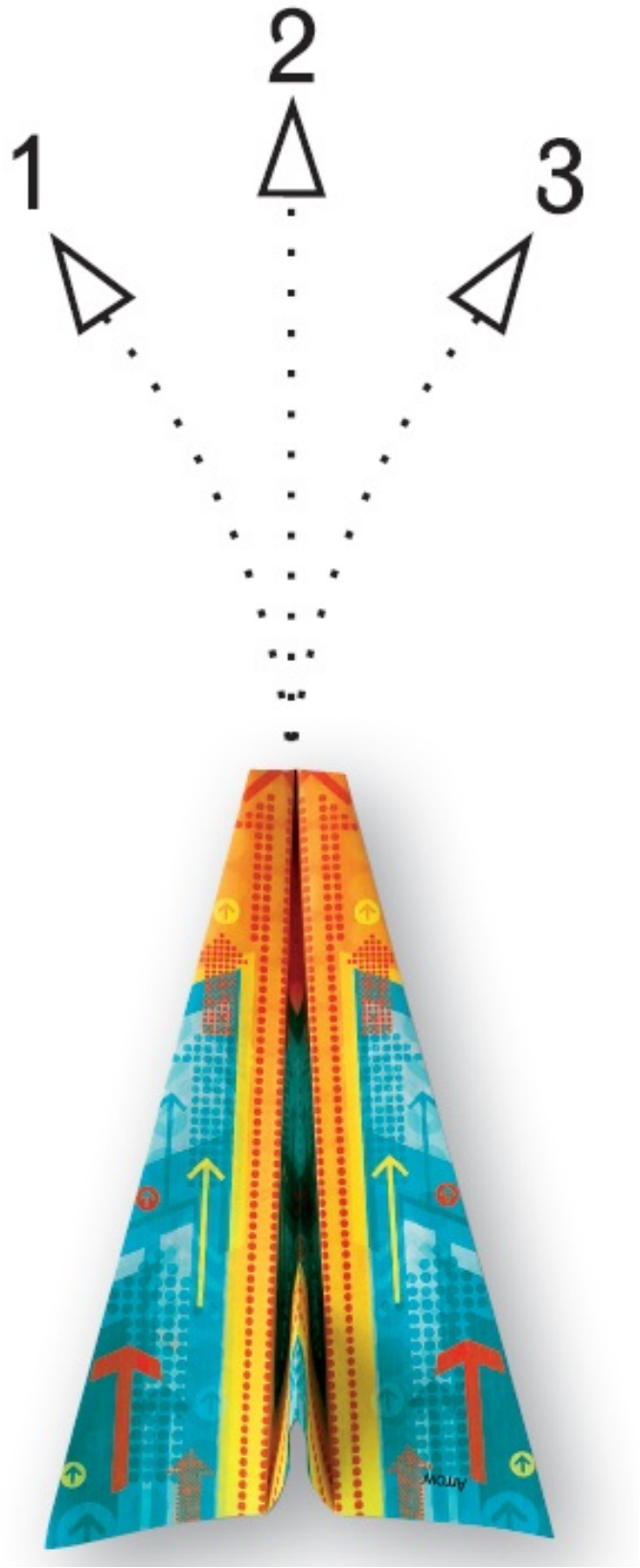
Just right!

B

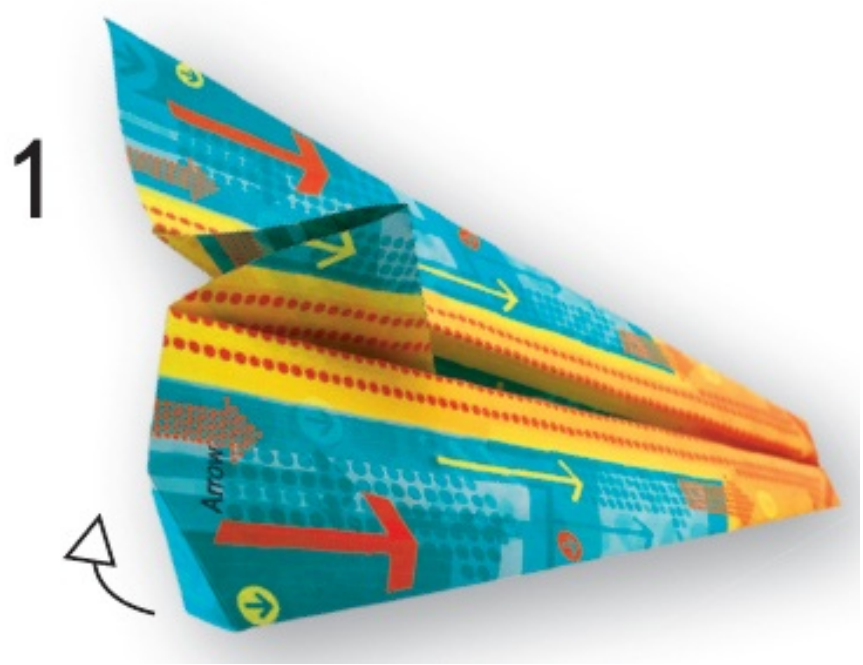
Fix a dive b y bending the back of the wing up slightly.

C

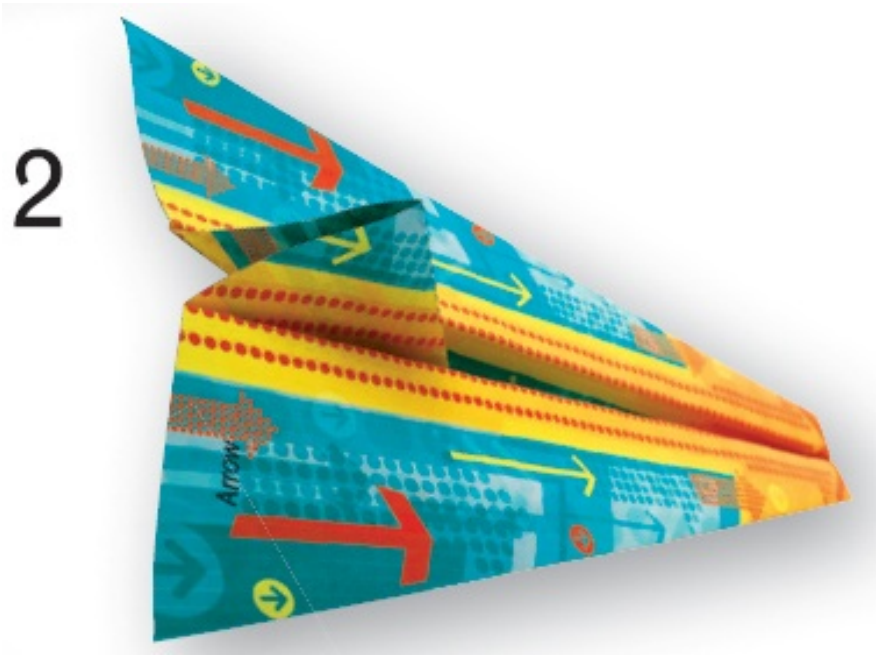
Fix a left turn by bending the back of the right wing up slightly.


1
2
3

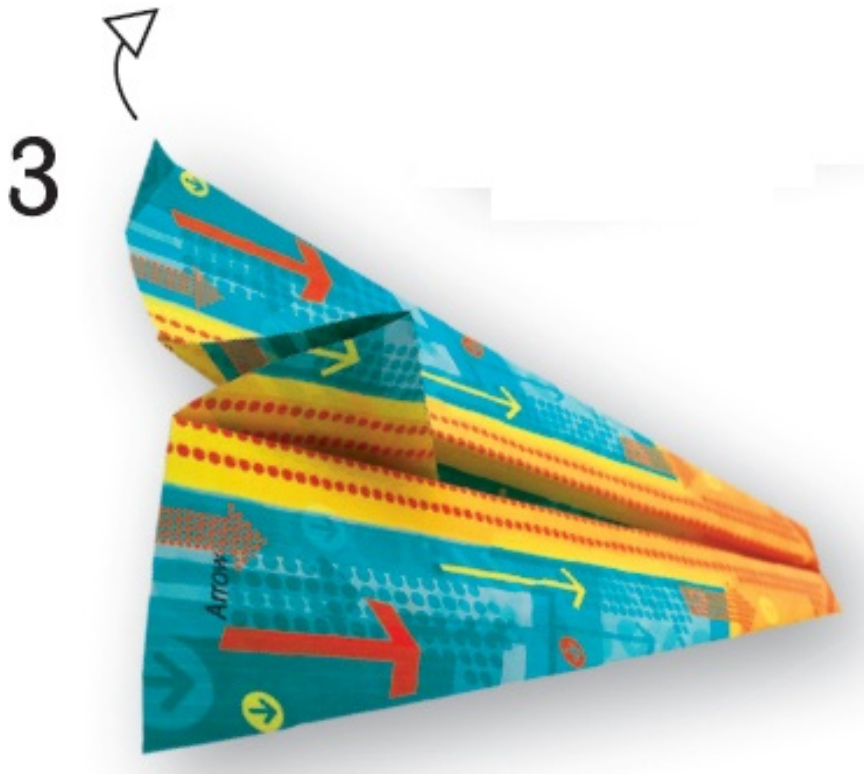
If your plane turns to one side or the other, adjust it until it flies straight as in pattern 2.



Fix a left turn by bending the back of the right wing up slightly.



Just right!



Fix a right turn by bending the back of the left wing up slightly.

The Importance of the Throw

Both Ken Blackburn and Takuo Toda throw with their whole bodies, starting crouched down with the plane all but touching the ground. But their form is quite different after that. Blackburn twists his torso while springing up from the waist, and in some pictures it looks like he's bent right over backwards. His plane starts facing down and is snapped upright partway through the launch. It swings up in a long arc, quite far from his body core. Toda pops up from the knees, so that the plane is slung up in a straight line quite close to his body. It is pointing upwards the whole time. Blackburn uses brute power, which his plane has to absorb; Toda's smooth throw accelerates the plane cleanly.

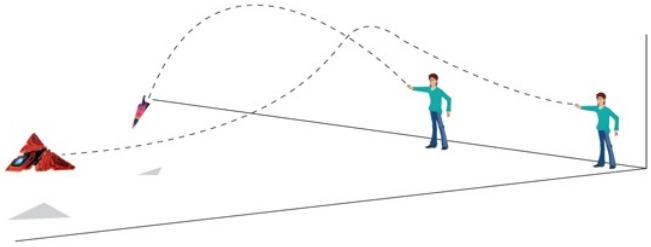
Blackburn has undeniable power, and his throws get lots of height, but the stress he puts on the airplanes is probably causing a big loss. The snap causes the wings to warp and flutter, which creates a lot of drag and makes it more likely the plane will swing off to one side or even crash.

Toda, on the other hand, keeps the plane heading straight in one direction through the whole launch, which means there is little stress on the wings, and

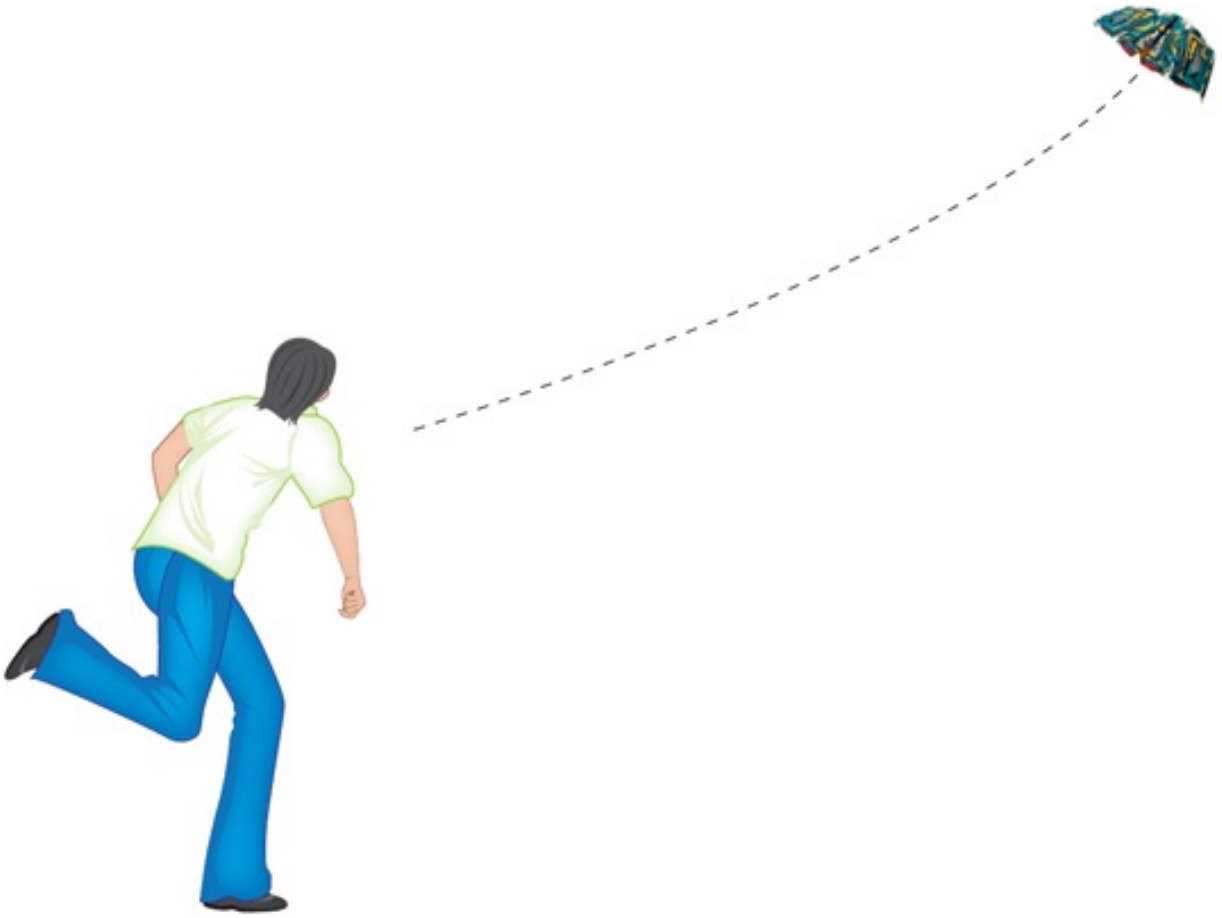
very little warping or flutter. The plane slices cleanly through the air as it rises. In fact, it looks more like it's gliding vertically than being thrown!

Diving for Speed

If you throw a screwed up twist of paper, it will go a long way. But not far enough. The record set by John Collins and Joe Ayoob—as long as 15 cars lined up end to end—was only possible because of the plane's special flight path. The wings were important, and so was the paper used in the plane. But it was the dive partway through that sent the "Suzanne" soaring past its rivals.



If you want to throw a ball as far as possible, you need to throw it up at a 45 degree angle. That will give it the greatest height and greatest distance. A bigger or smaller angle will make it fall short. That's because the ball follows an arc. It is slowing down and falling as soon as it leaves your hand. A plane like a dart with tiny wings will fly just the same way, up and down, no farther than you can throw it.



But Joe Ayoob threw the "Suzanne" at a much smaller angle—almost horizontal— after which the lift from the wings made it climb up almost to the ceiling. When the speed dropped off, the plane nosed down, dove for the floor, and then with the renewed speed from the dive, flared into a long flat glide right across the hangar. In other words, the plane got its flying speed from both Ayoob's arm and the height it climbed to. Getting the angle and throwing speed right to just miss the ceiling and lengthen the glide at the end is the secret to capturing the record.

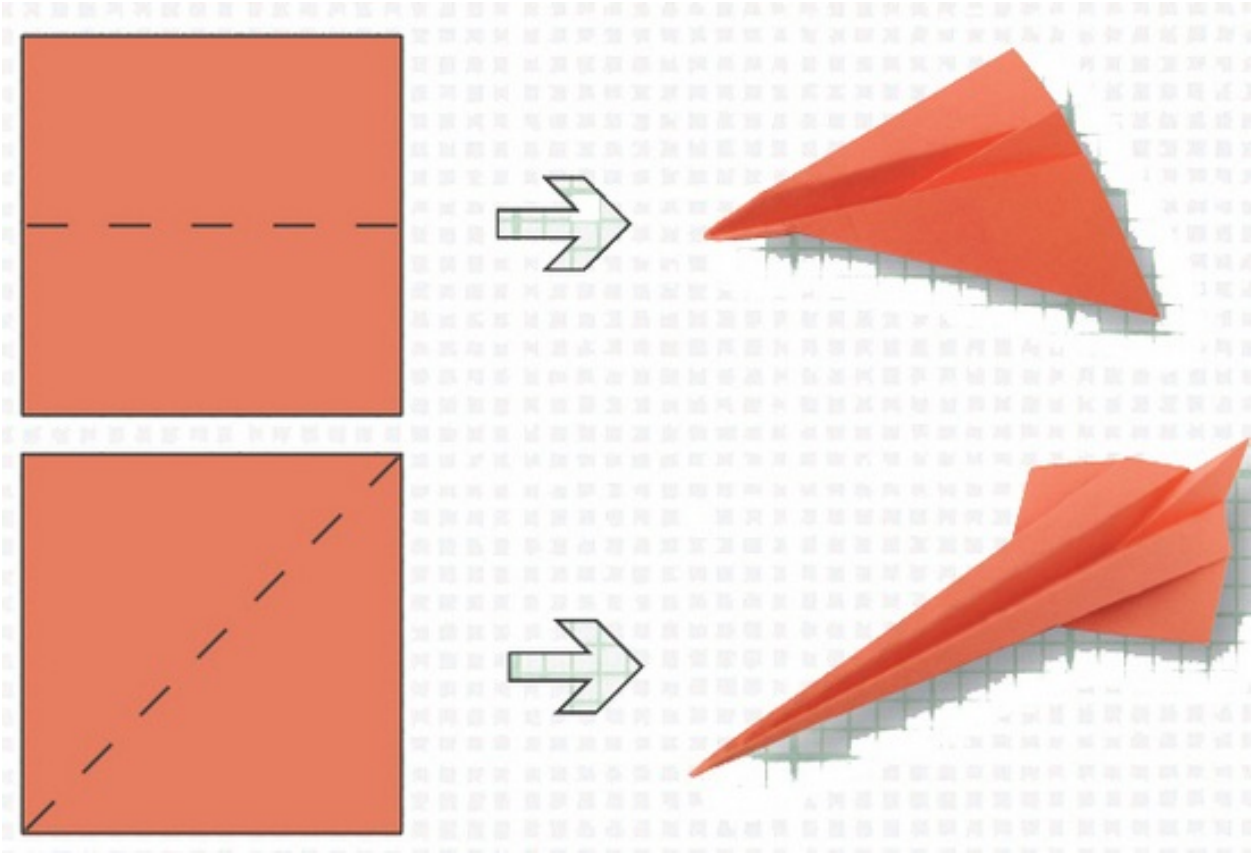
Designing Your Own Airplanes

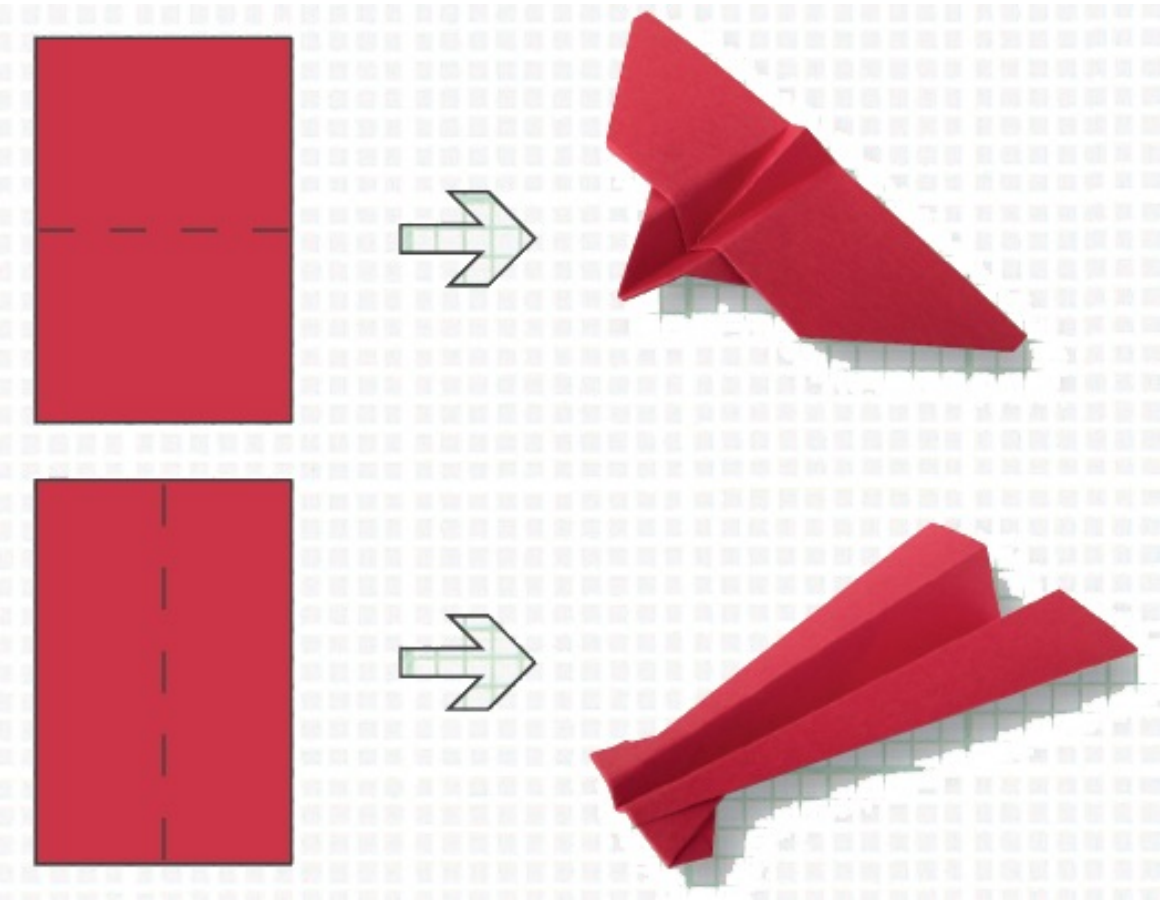
Many people seem to think there's a kind of magic to designing origami airplanes. I hope you're not one of them! There's no magic involved. In fact, it's mostly just fiddling with paper, folding and flying, folding and flying, and tossing the planes into either a box of successes or the recycling bin. But how exactly do you go about designing a new plane? Here are some things to keep in mind.

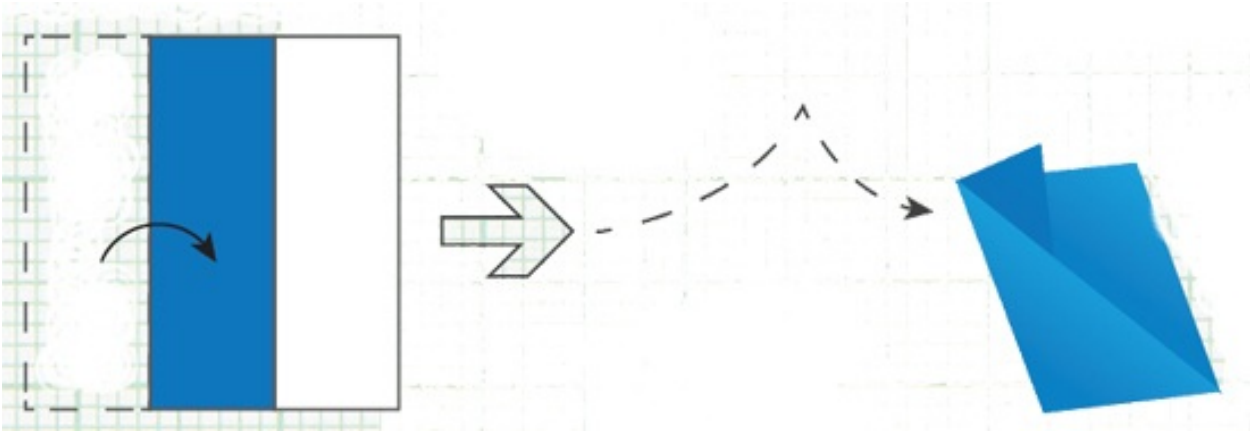
Just as a journey of a thousand miles begins with a single step, a new airplane begins with a center fold. If you are using square paper, your first fold can either be straight from side to side, or diagonal from corner to corner. A diagonal centerline will give you a longer plane with a pointy nose, short, triangular wings and maybe a swept-back tail. Folding across the paper creates a shorter, blunter plane.

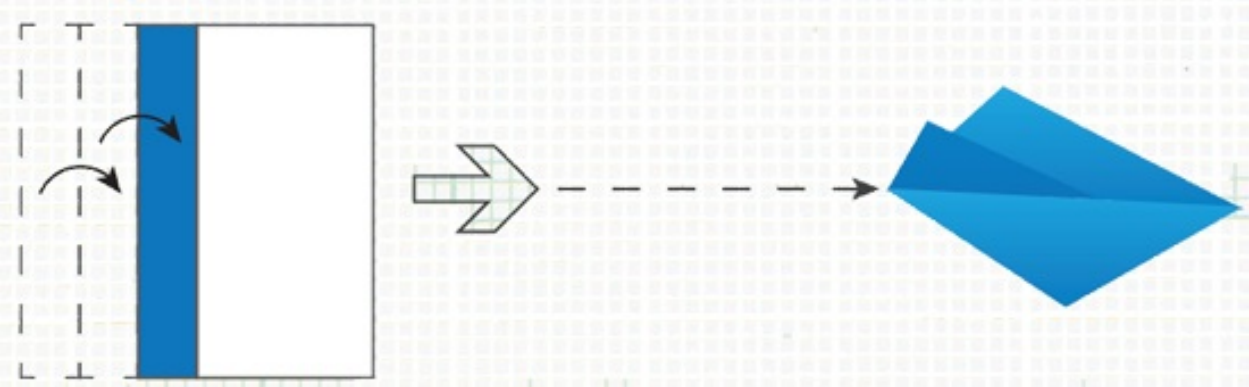
Rectangular paper can be folded either the long or short way, to give you either a long, narrow plane that flies fast, or a plane with long wings that flies slowly and gracefully.

Other center folds are possible (like the Aerospike fold, page 56), but you may want to wait until you are comfortable with the basics before trying them. Or, just go for it!

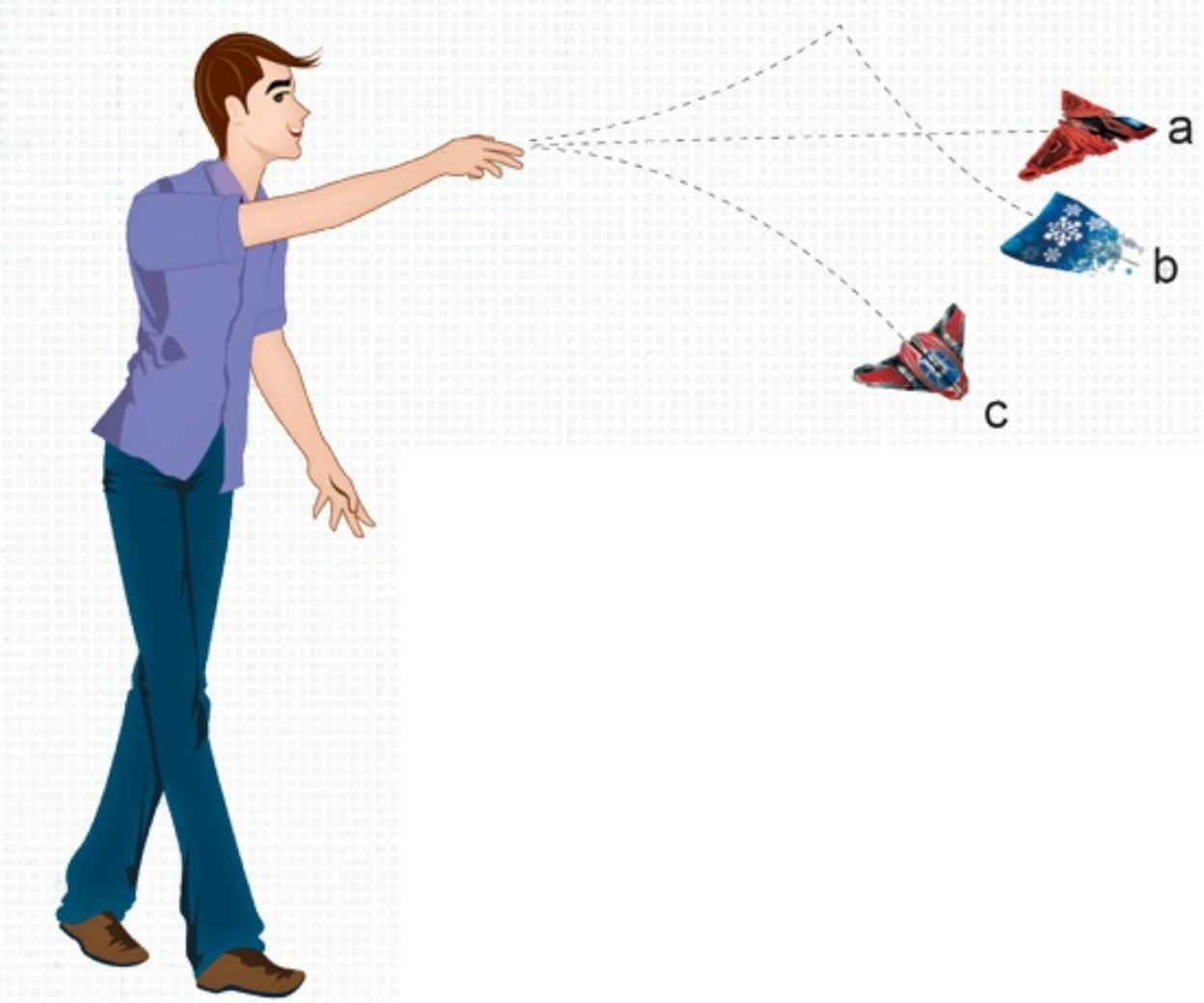




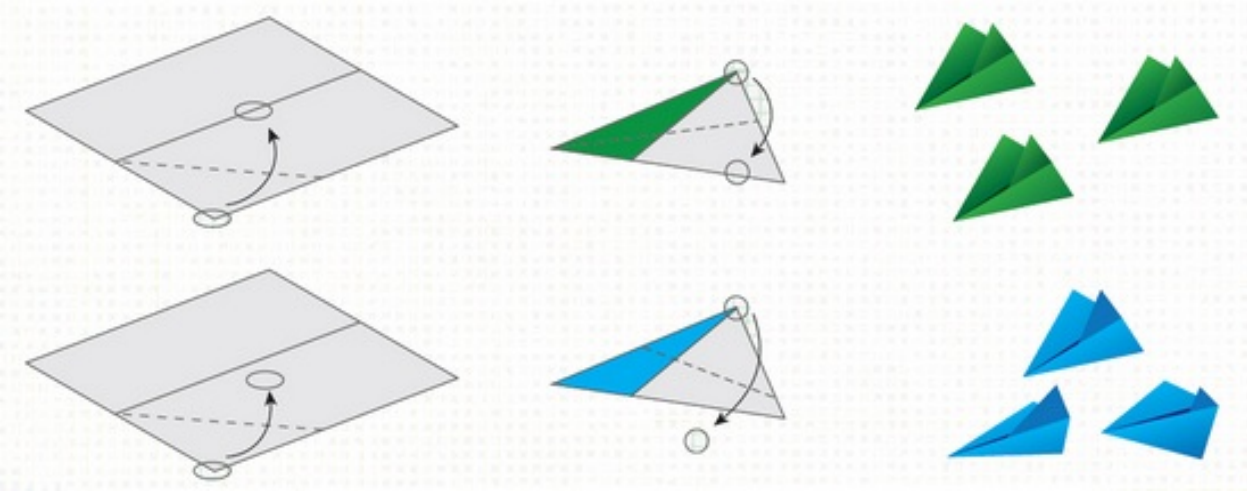




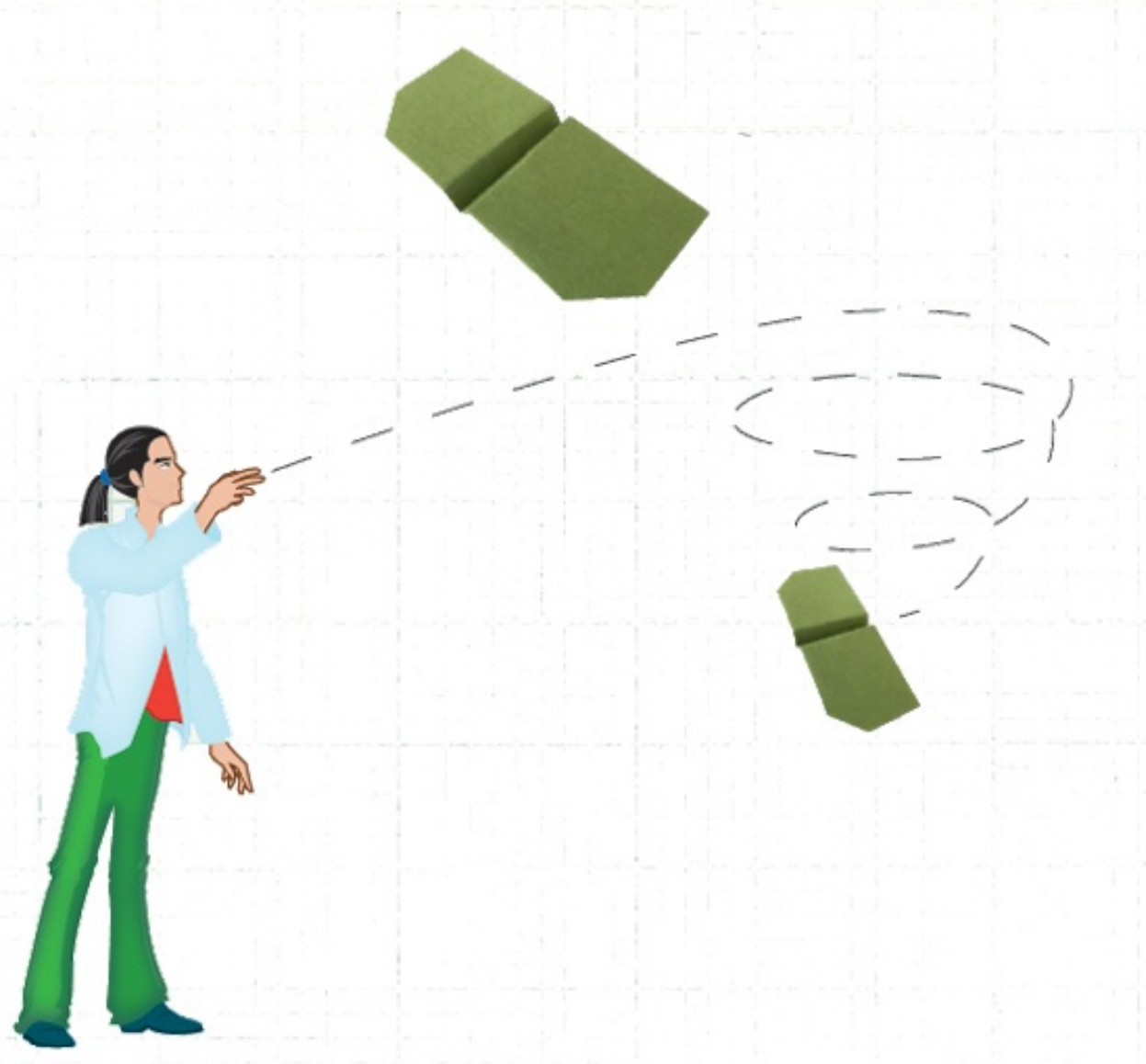
Your first big worry will be balance. You need to make the nose heavyish, so the center of gravity will be in the right place. If the nose is too light, the plane will flip up and stall. (If the nose is a tiny bit heavy, you can adjust the back of the wing and get away with it.) Make the nose heavier by adding more folds at the front, and by keeping as much paper as far forward as possible.



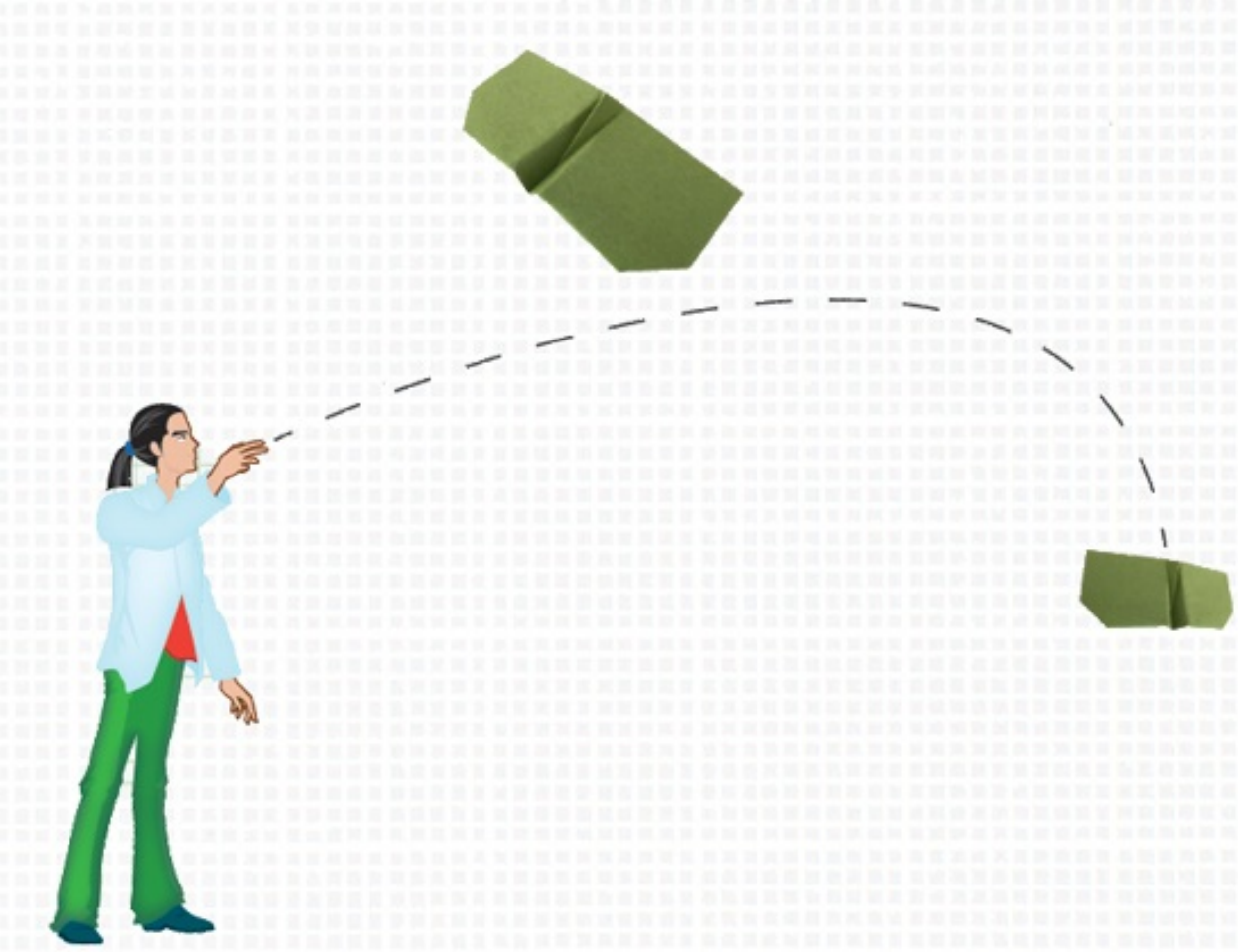
Another trick for adjusting the center of gravity is to change the shape of the wings. If the plane stalls, as in flight pattern b, make the wings smaller at the front. This moves the center of lift back, which is the same as making the nose heavier. If the plane dives like pattern c, make the wings bigger at the front or smaller at the back. If the plane flies like pattern a, don't touch a thing, because it's perfect!



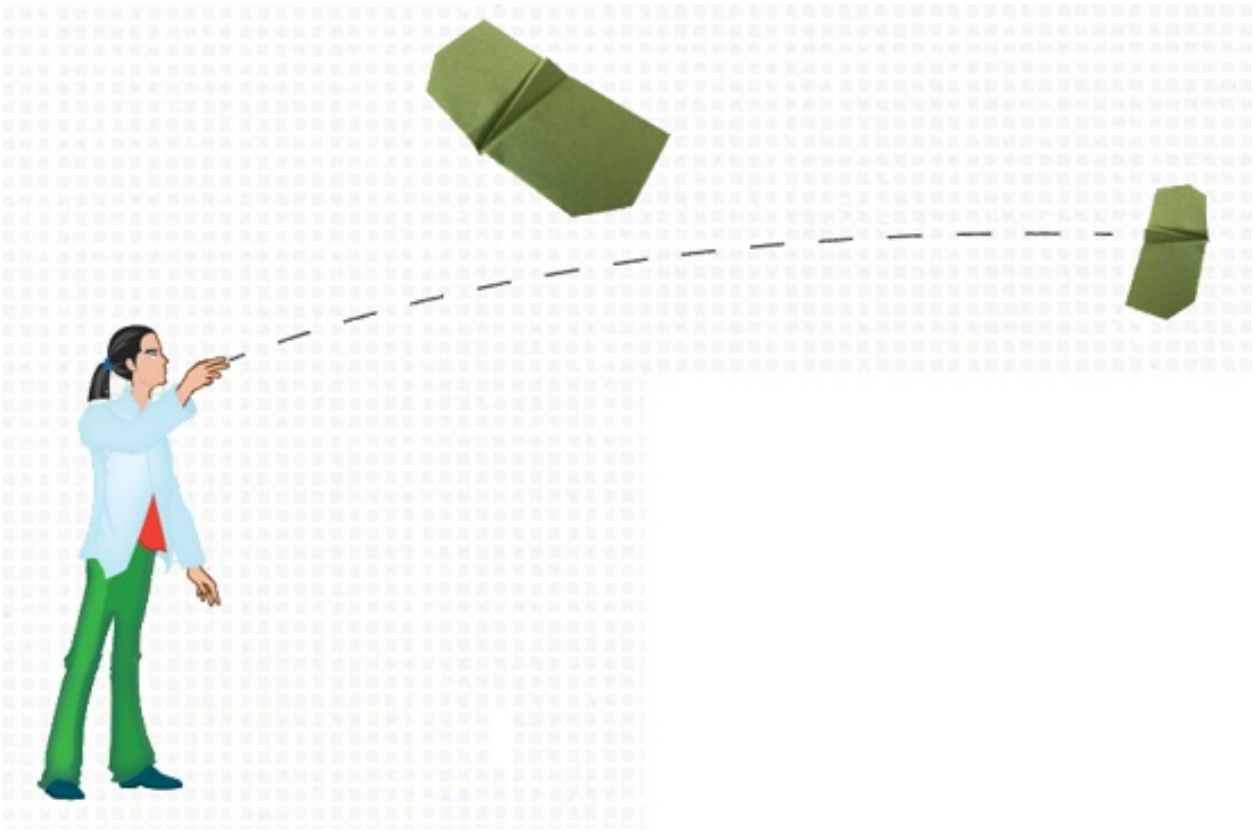
You'll probably notice, when you start folding the planes in this kit, that every design uses "landmarks" to help know where to fold. Why? Reproducibility. If your design is any good, you'll want to make more of it. And if you want to try for a record, you'll probably need to fold and fly dozens or hundreds of them. If you design it with corners touching corners, edges meeting edges, sides folded in half, and other landmarks that show exactly where to fold, you can make as many of your design as you like, and so can someone else! If you ignore the landmarks and just fold at random, you might make an amazing plane, but it will be unique; you won't be able to make another quite like it.



You also need to be sure you have enough rudder or a big enough fin at the back of the fuselage to keep the plane going straight. If the fin area is too small, the plane will spin and crash. If it flies for a little bit and then veers to one side no matter what you do, it is still too small. You can make it bigger by making the wings a little smaller. Or add wingtip fins.



Not all of the planes will work out. Don’t worry! It’s just paper! If you wad them up and shoot some baskets, they’ll still be lots of fun.Fold and fly, fold and fly, fold and fly. Make little changes each time and see how they affect the flight. Cut up newspaper inserts make great paper for prototyping. You’re going to want lots!

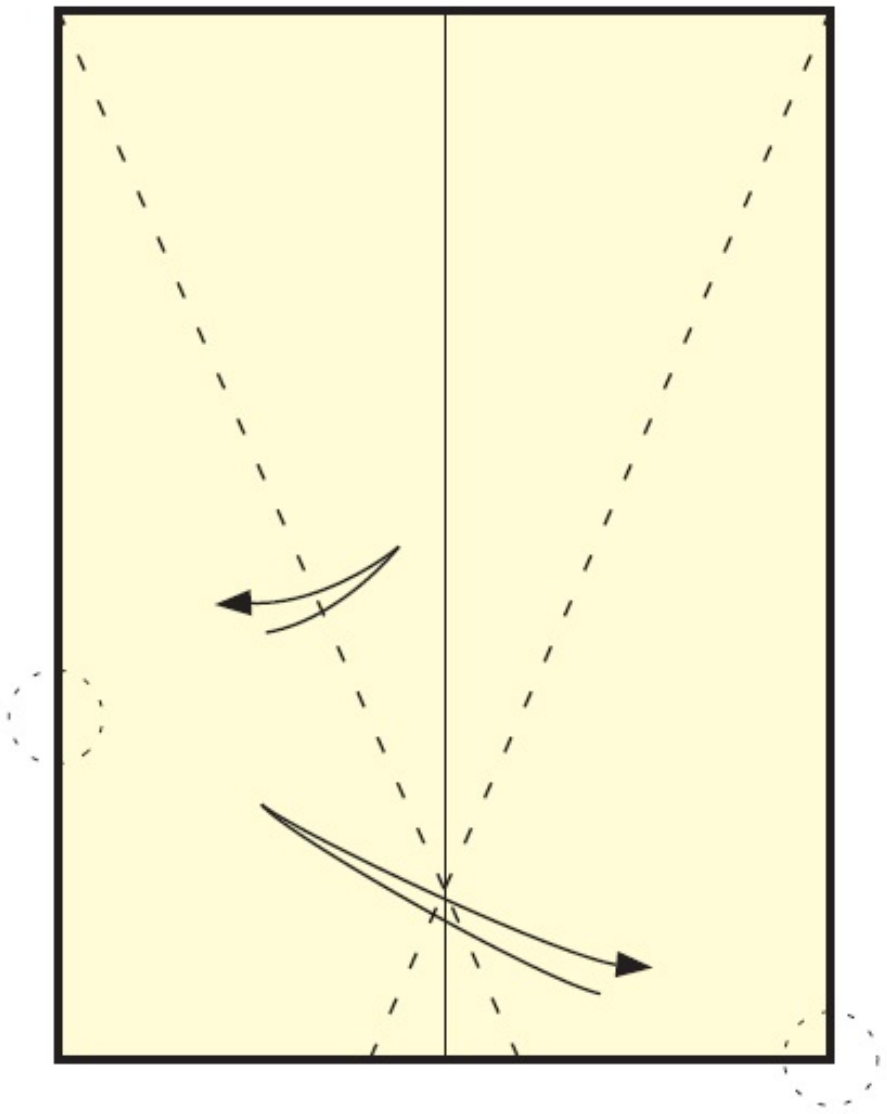


0 CM
1
2
3
4
5
6
0
10
20
30
150
160
170
180

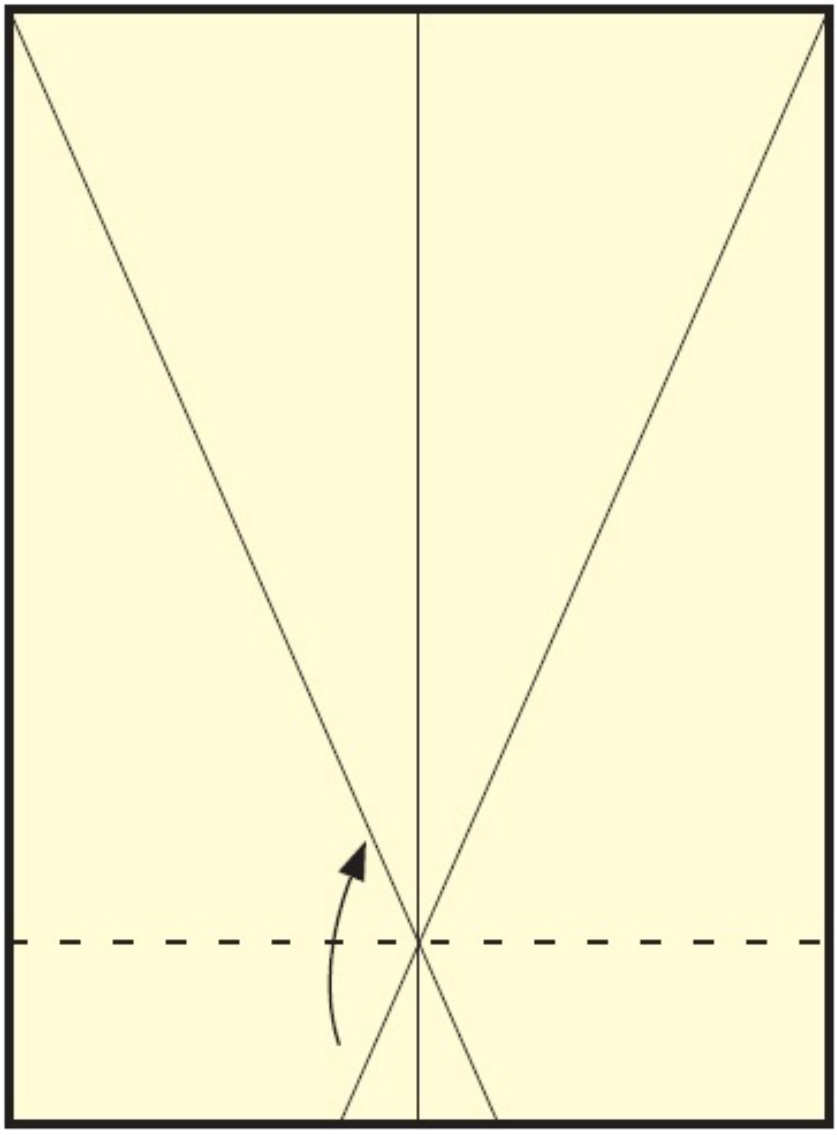
THE DELTA DART

At first glance, this plane looks just like the classic dart airplane you made at school. But it has the front part of the paper folded up to make the nose heavier. That will help it go a long way!

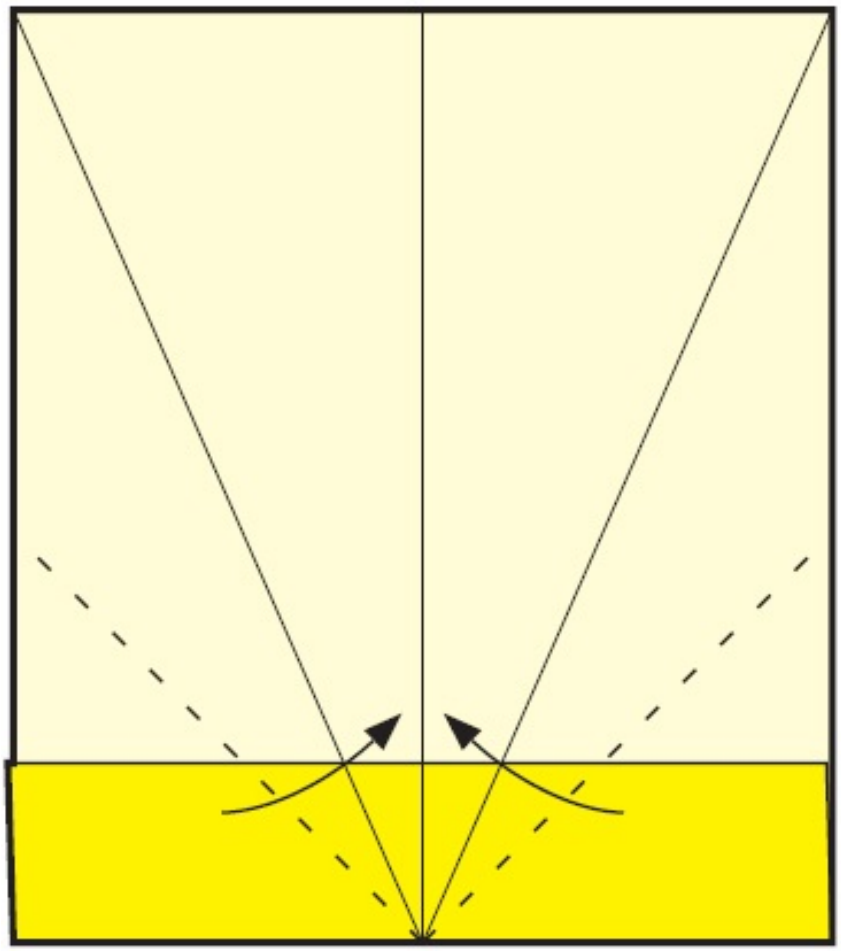
Author's Average Distance Flown: 20 Yards



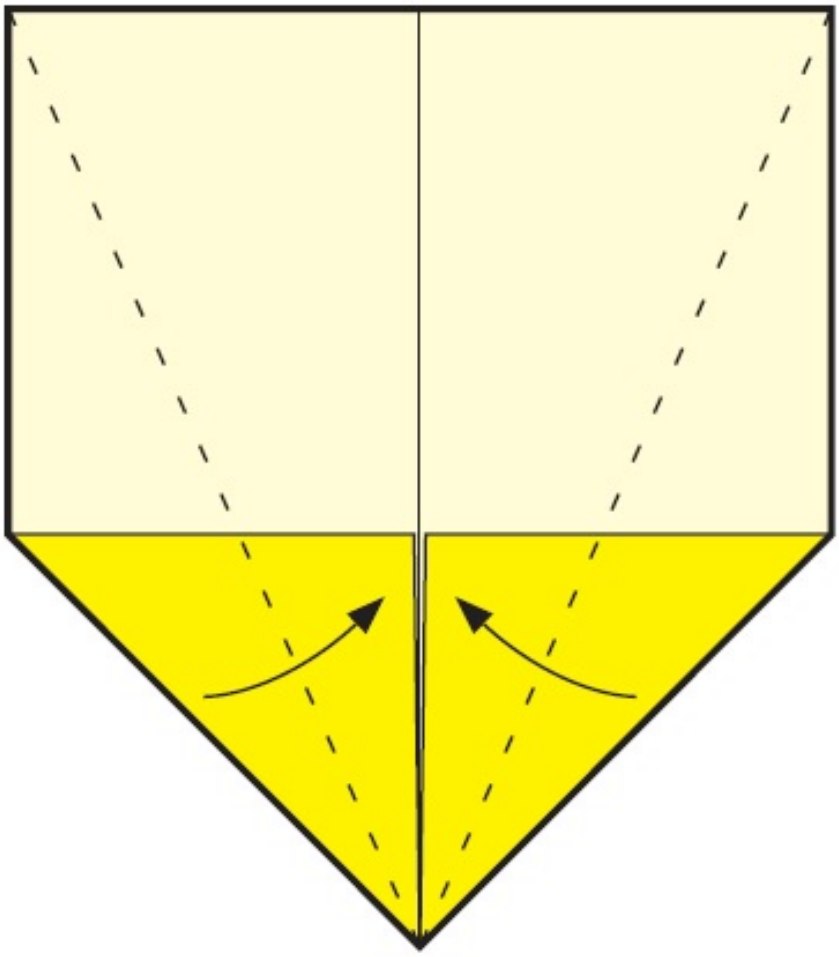
1 Start with the paper face down. Fold and unfold on the 1 lines. The corners of the paper should just touch the opposite edge.



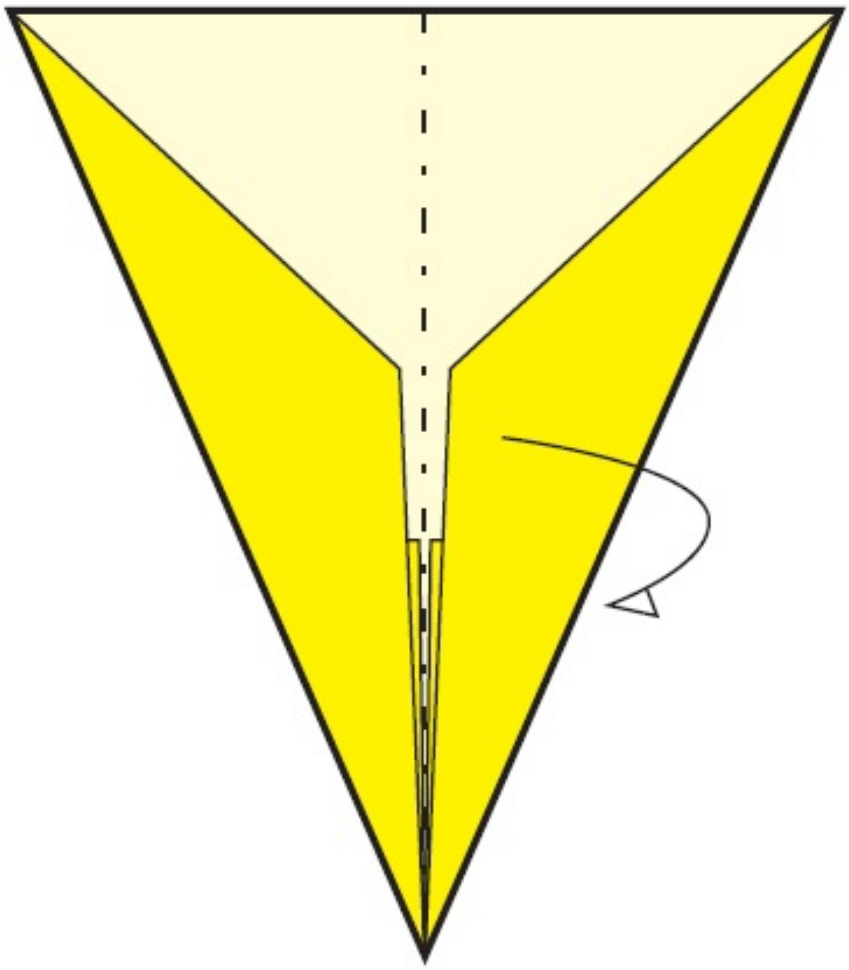
2 Fold up on line 2, where the two creases cross at the center line.



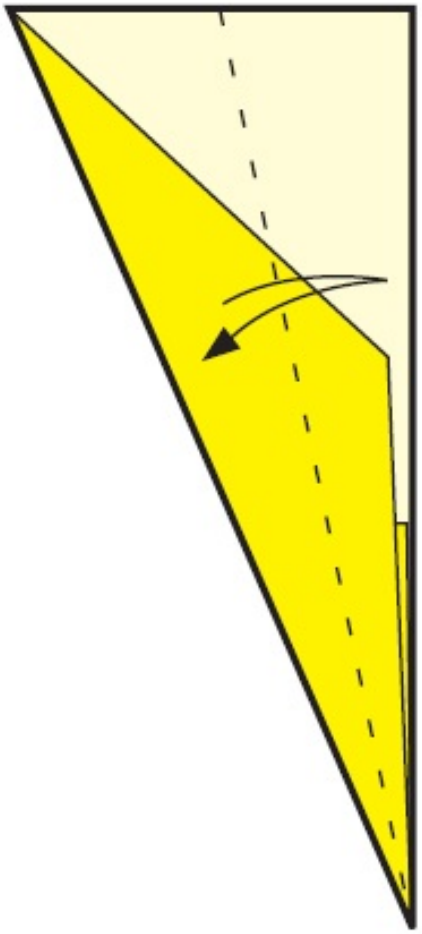
3 Fold the bottom corners in to the center line on the 3 lines.



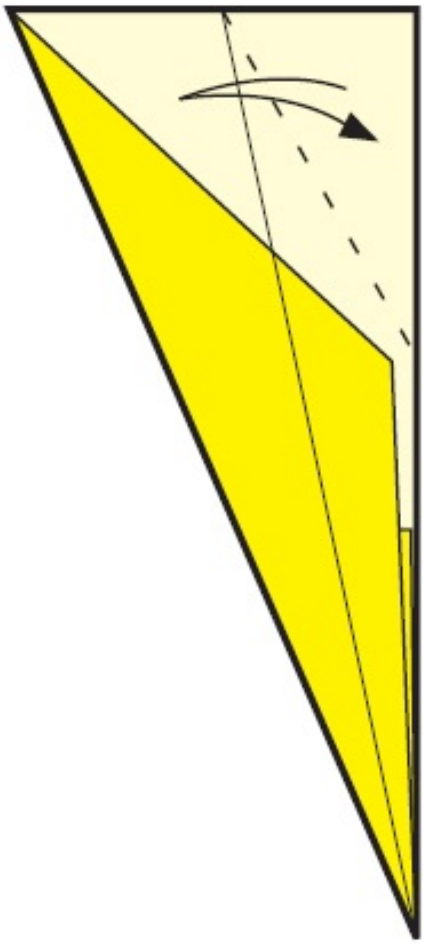
4 Recrease the 1 lines.



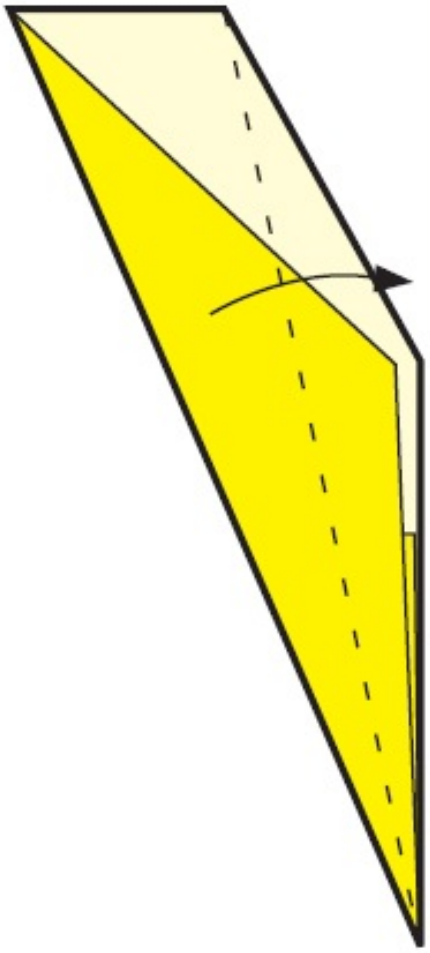
5 Fold the plane in half away from you.



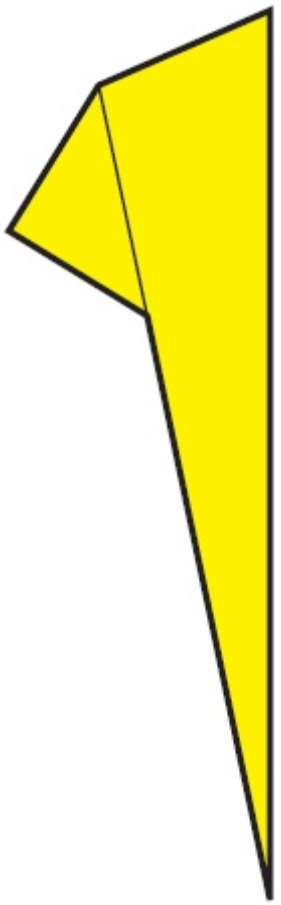
6 Fold and unfold the wings on the 4 lines. The outer edges should match the center line.



7 Fold and unfold the rudder on line 5.



8 Reverse fold the rudder, and fold the wings down again.

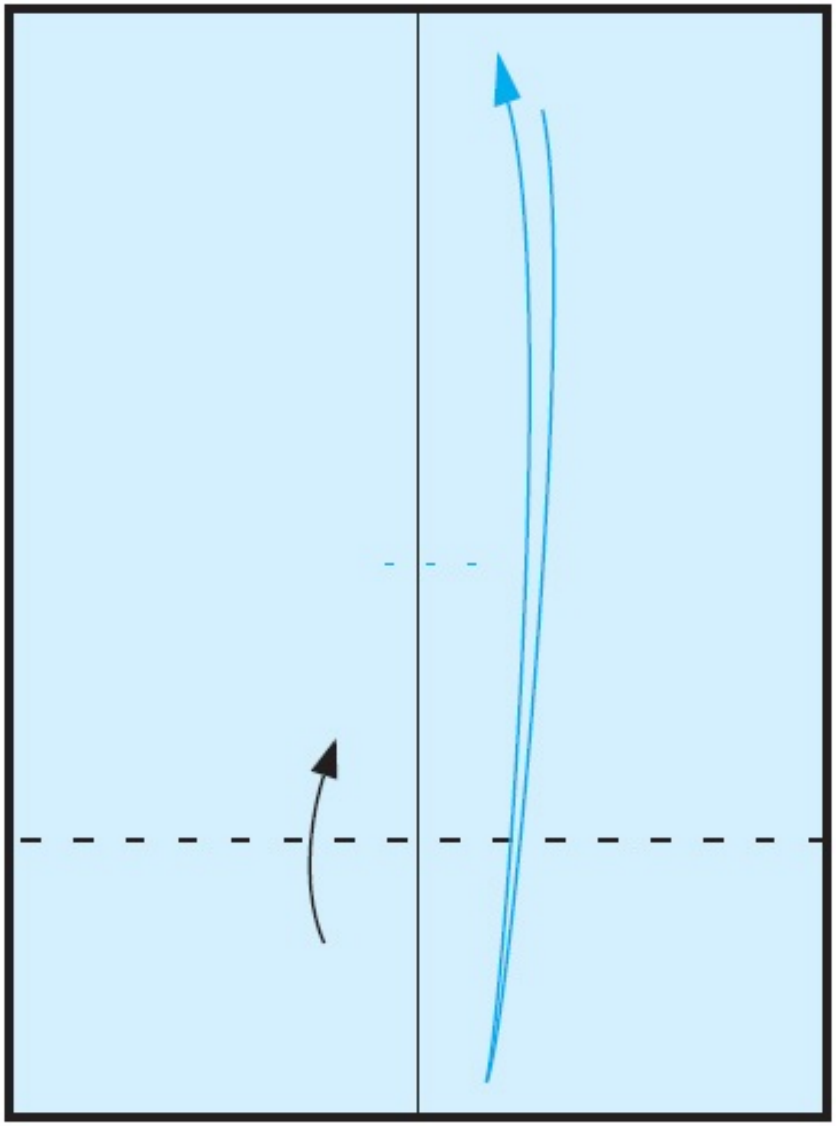


9 Straighten out the wings, and you're done!

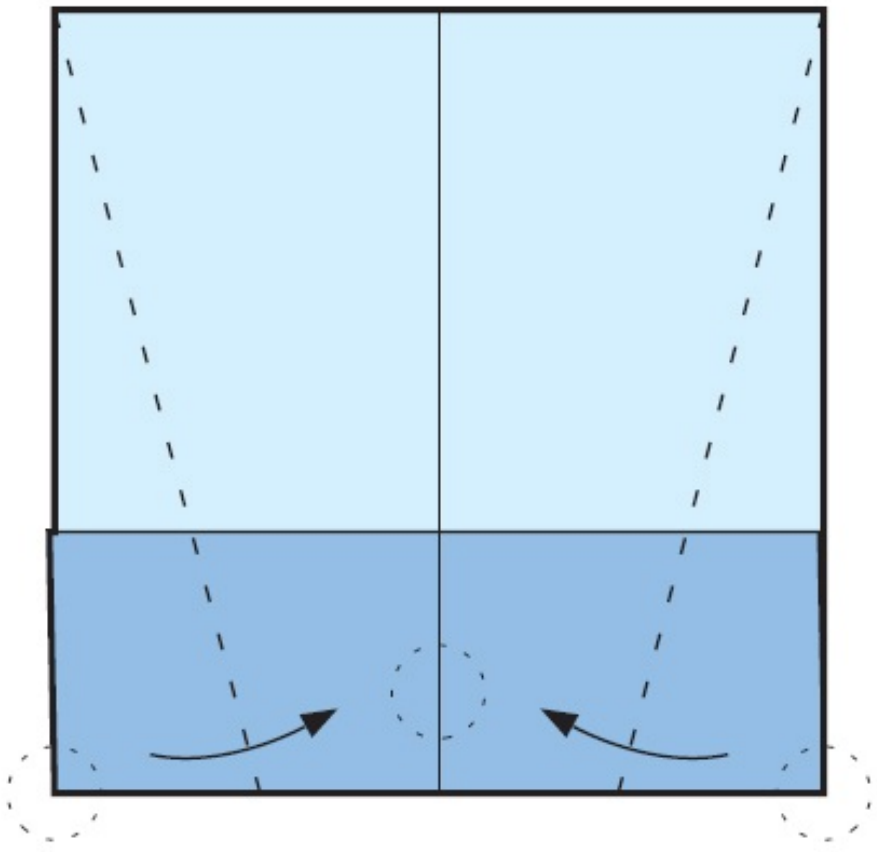
THE ARROW

This plane can be made in two versions: with and without the rudder. It will fly great either way, but without the rudder it will need a little more trimming at the back of the wing. Which goes farther? Try and see!

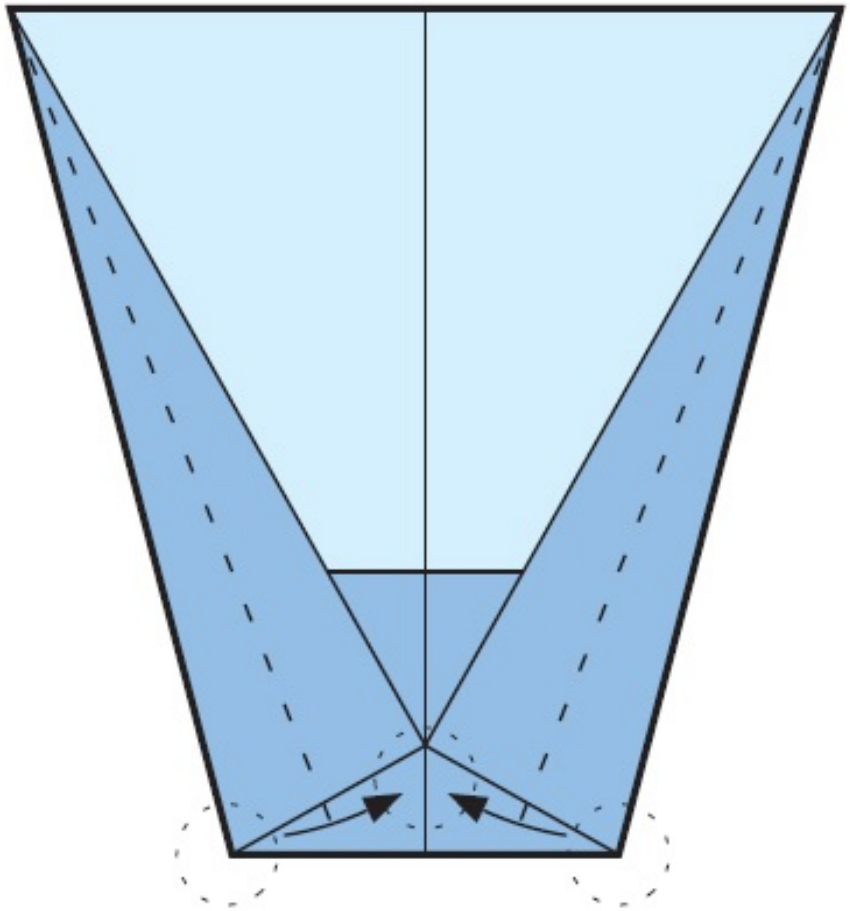
Author's Average
Distance Flown:
23 Yards



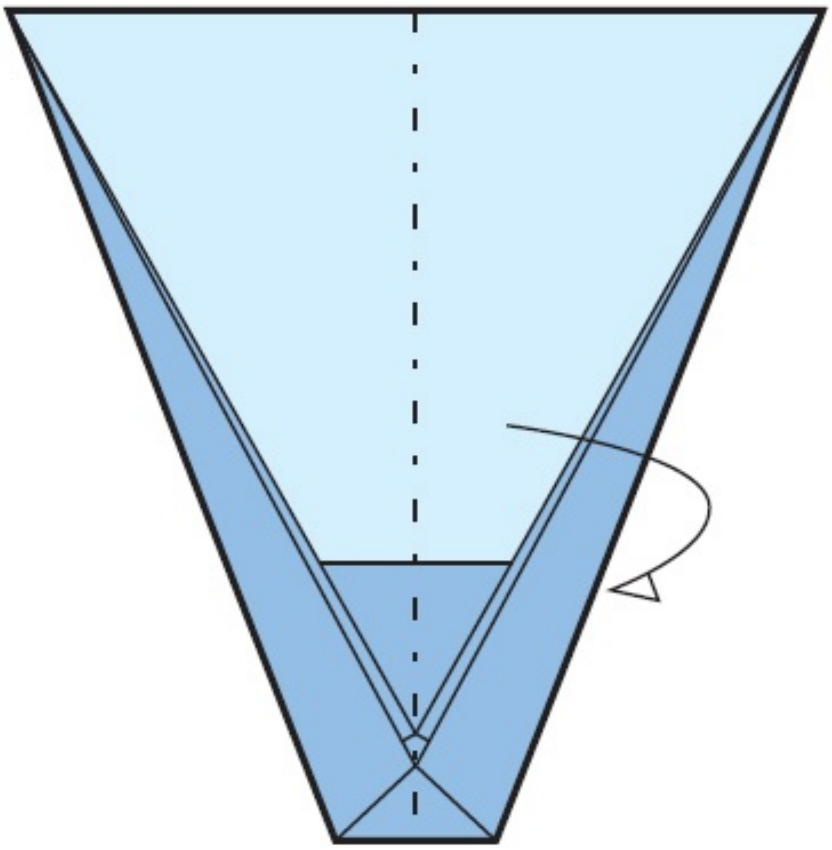
1 Start with the paper face down, and fold the bottom edge up to the middle on line 1.



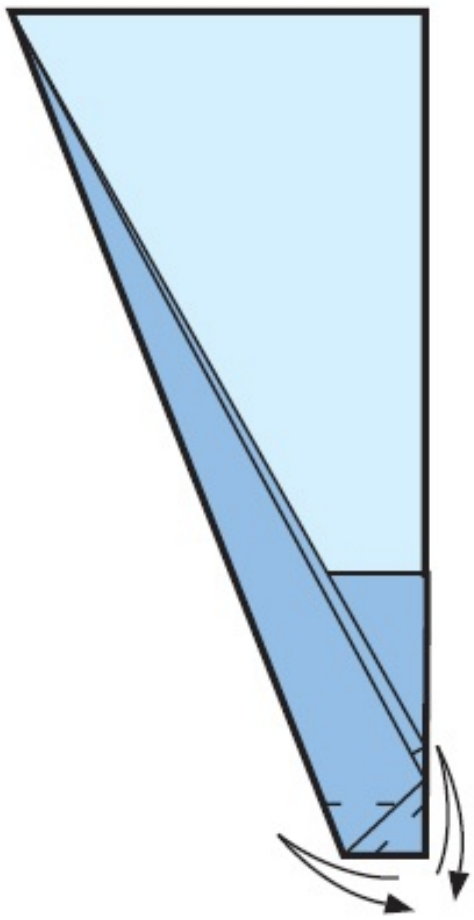
2 Fold the bottom corners in to the center line on the 2 lines as shown.



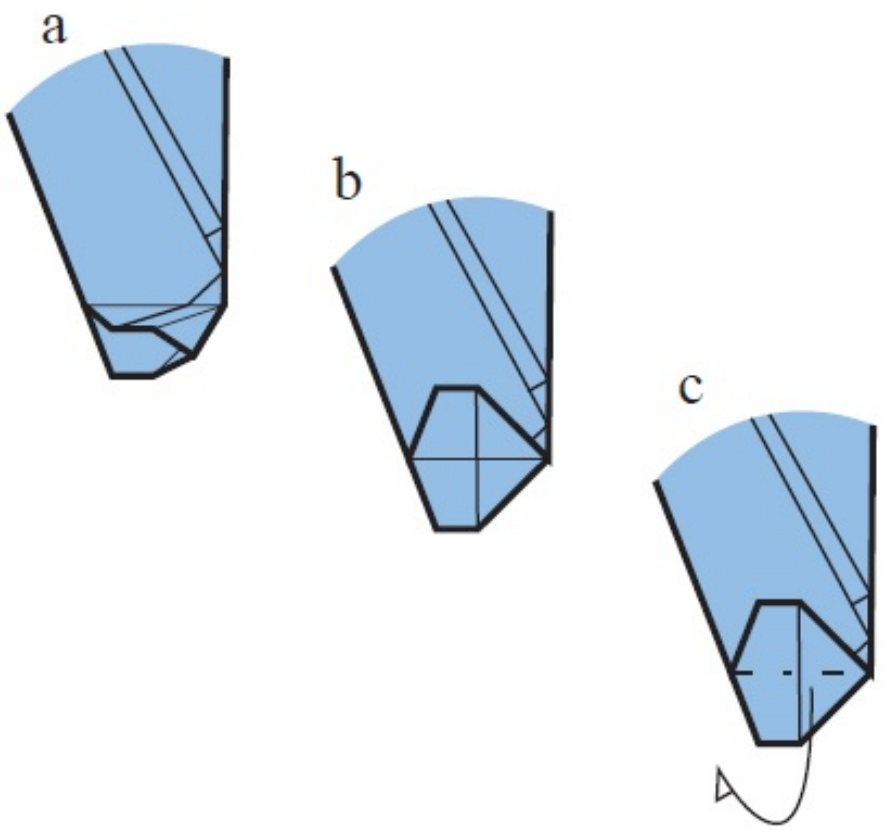
3 Fold the corners in again, the same way, on the 3 lines.



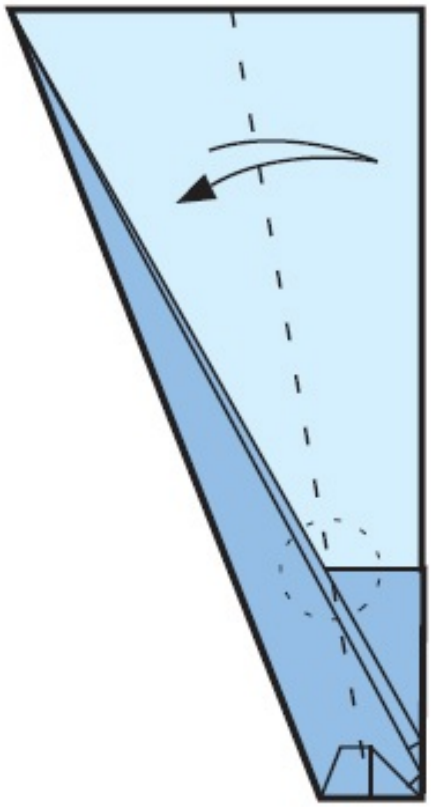
4 Fold the plane in half away from you.



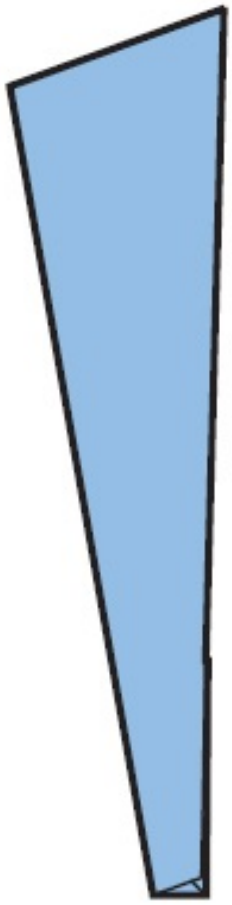
5 Fold and unfold on lines 4 and 5. The crease at 4 starts where the paper gets thick under the folded edges.



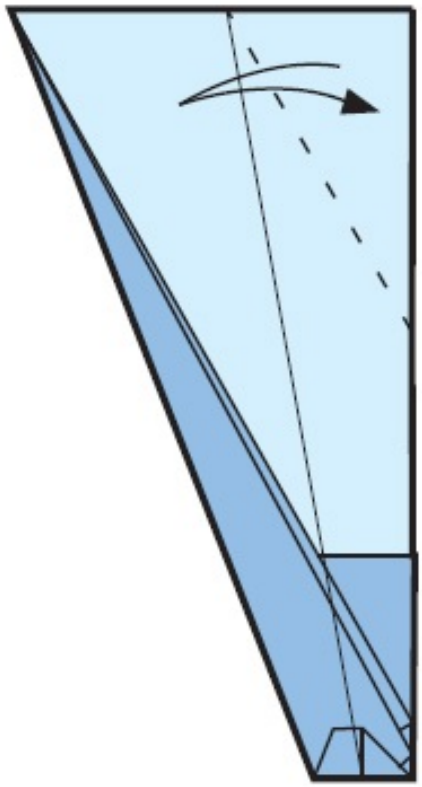
6 Pull the top layer of the nose up and fold it right back over. The bottom right corner will flip up and flatten on the 5 lines. Fold the lower layer to the other side.



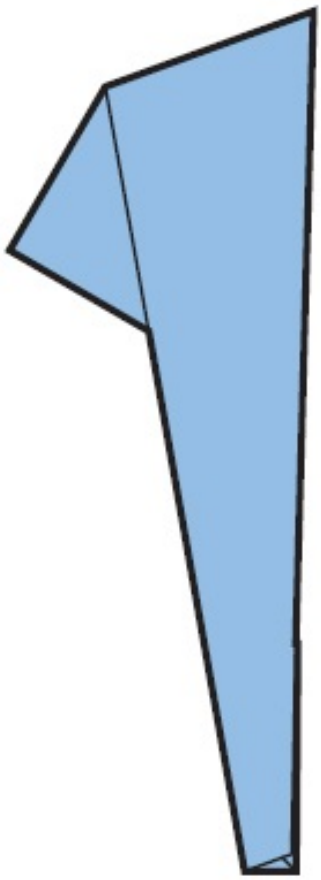
7 Fold and unfold the wings on the 6 lines. The fold starts at the loose edge in the nose and crosses the point where the edges meet, as shown by the circle.



8 This is how it will look. You can finish and fly your plane at this point, or carry on to the next steps to make a rudder.



9 Optionally, fold, unfold and reverse fold the rudder on line 7.

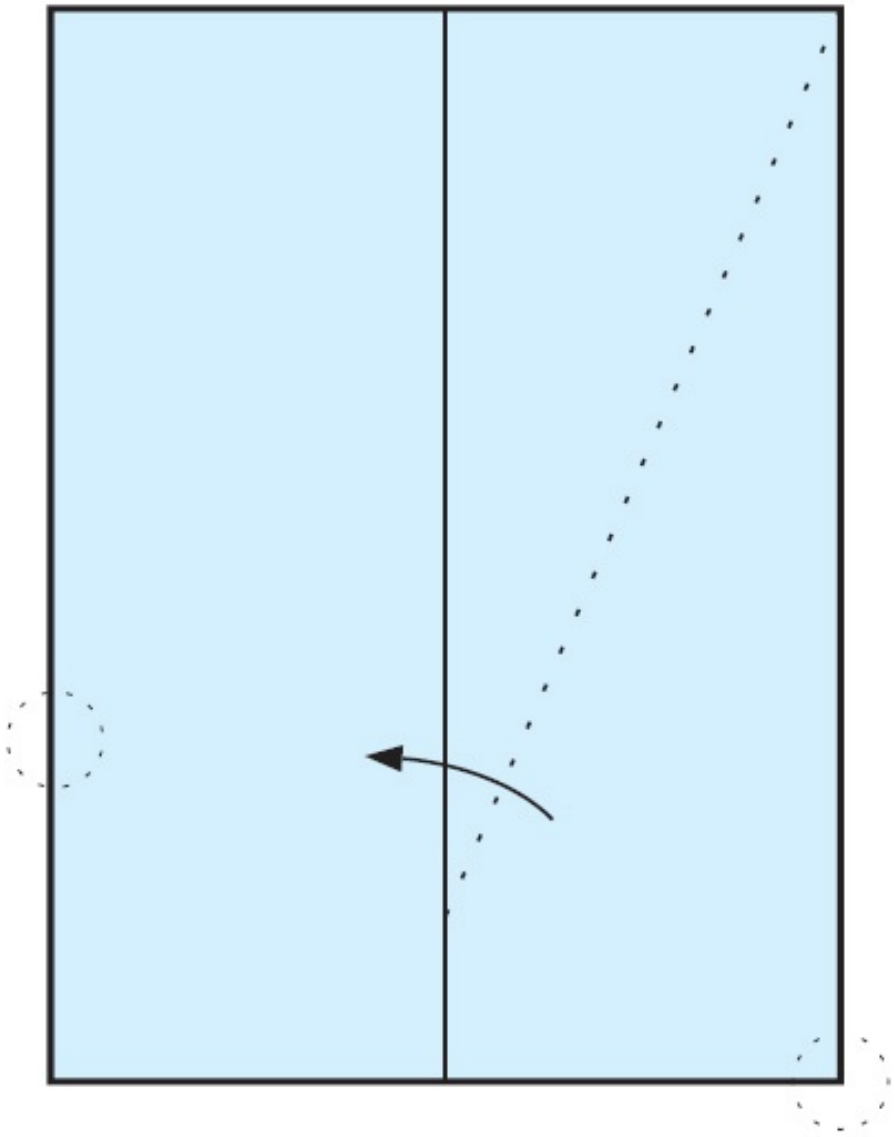


10 When you refold the wings, the plane will look like this. Spread the wings a bit and you're done!

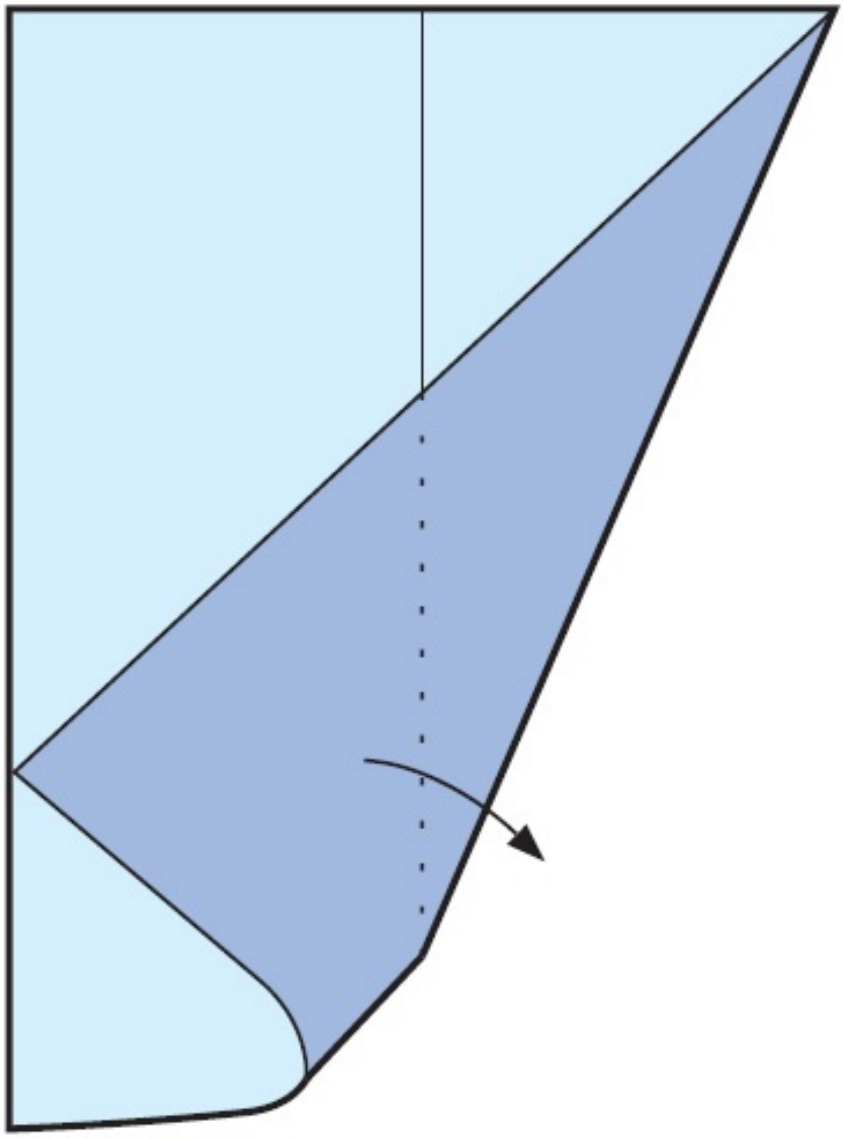
THE SPRINT

This plane is a version of the squid airplane, very popular in Japan. It is heavy at the front, which helps it fly straight and far, and the little wings at the front keep it from stalling and crashing, the main weakness of distance planes.

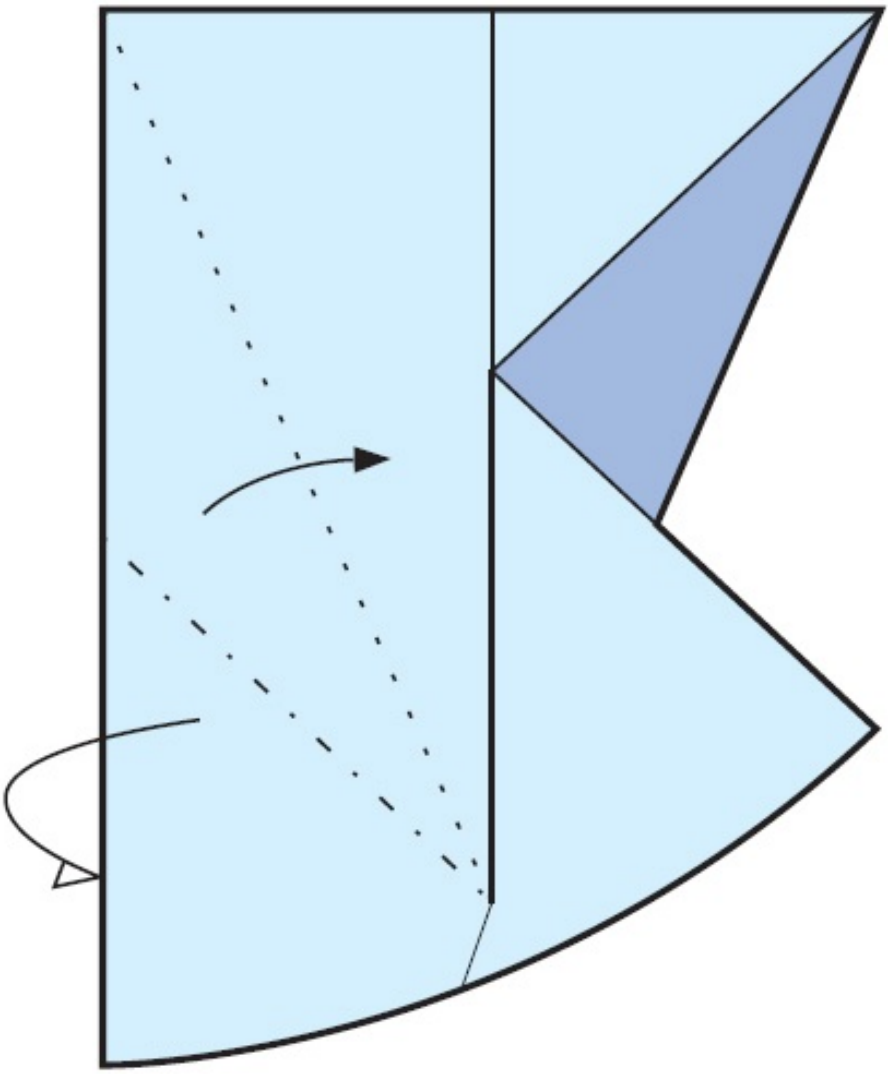
Author's Average
Distance Flown:
37 Yards



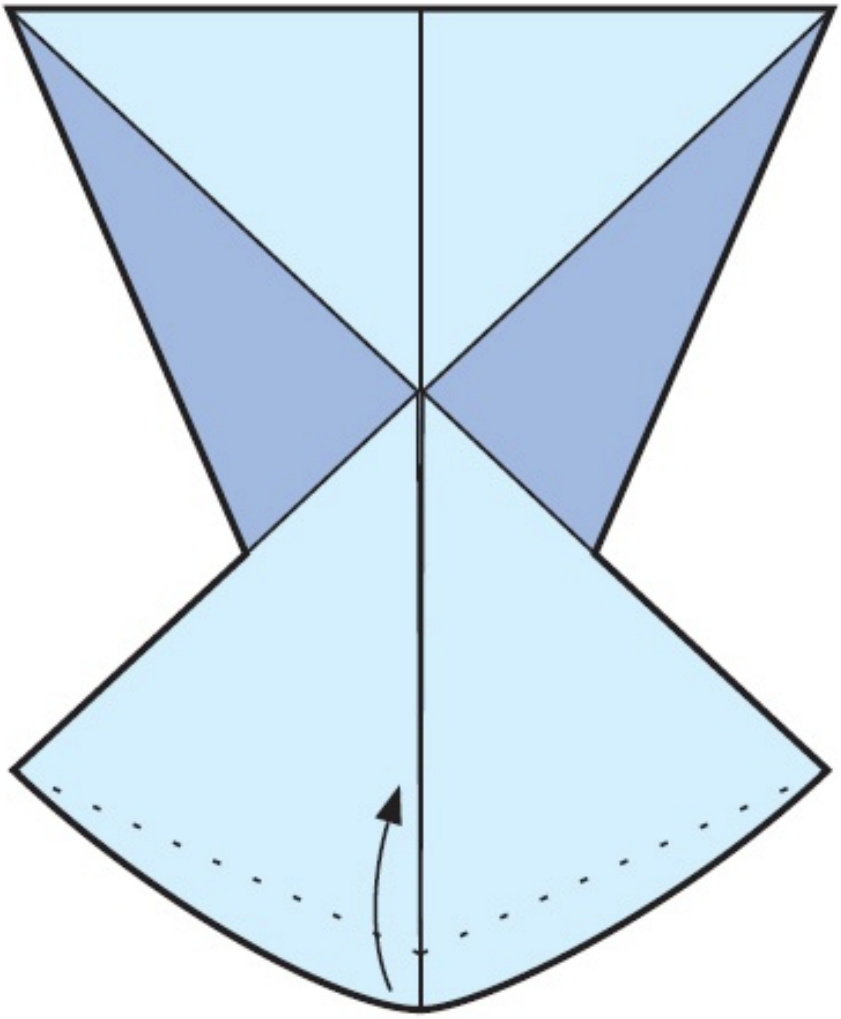
1 Start with the paper face down. Fold the bottom right corner across to the opposite edge. Crease on line 1 as far as the center line.



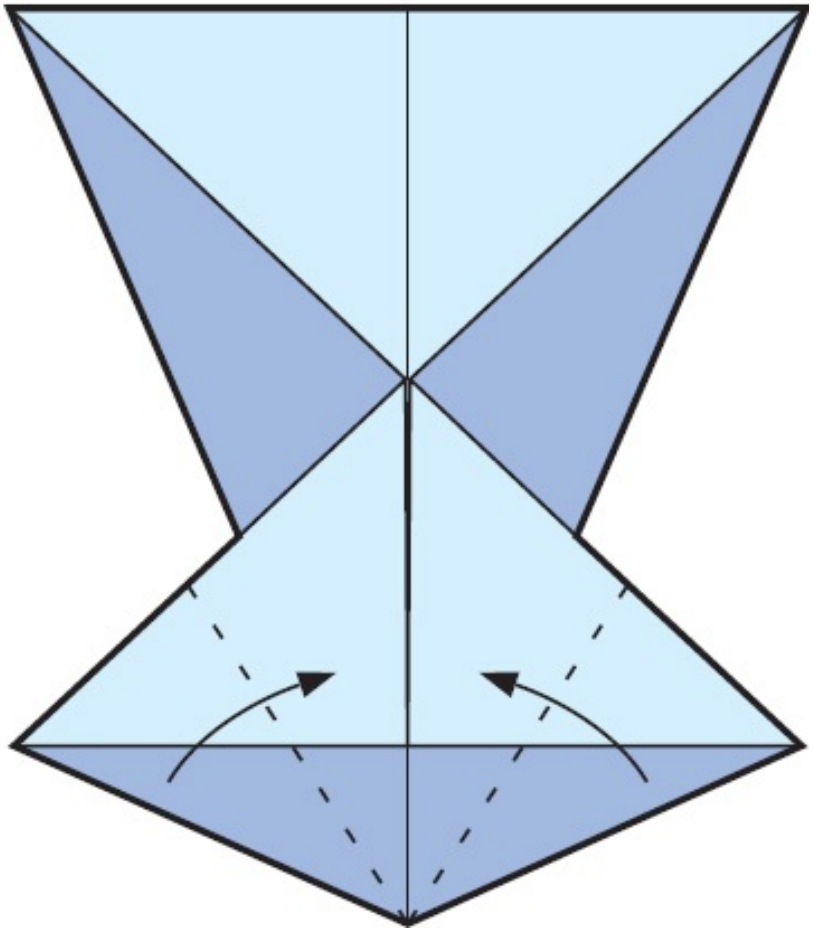
2 Fold the corner back outwards on line 2.



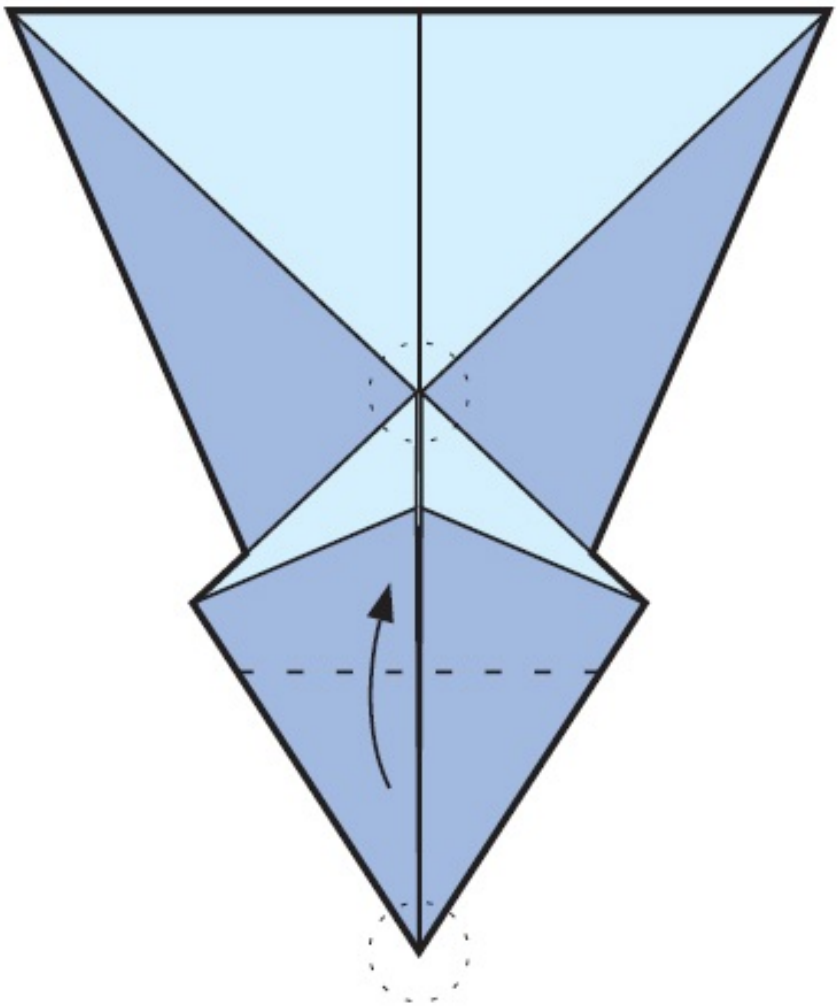
3 Repeat the first two steps on the other side, with lines 3 and 4. You should have a kind of pocket at the bottom.



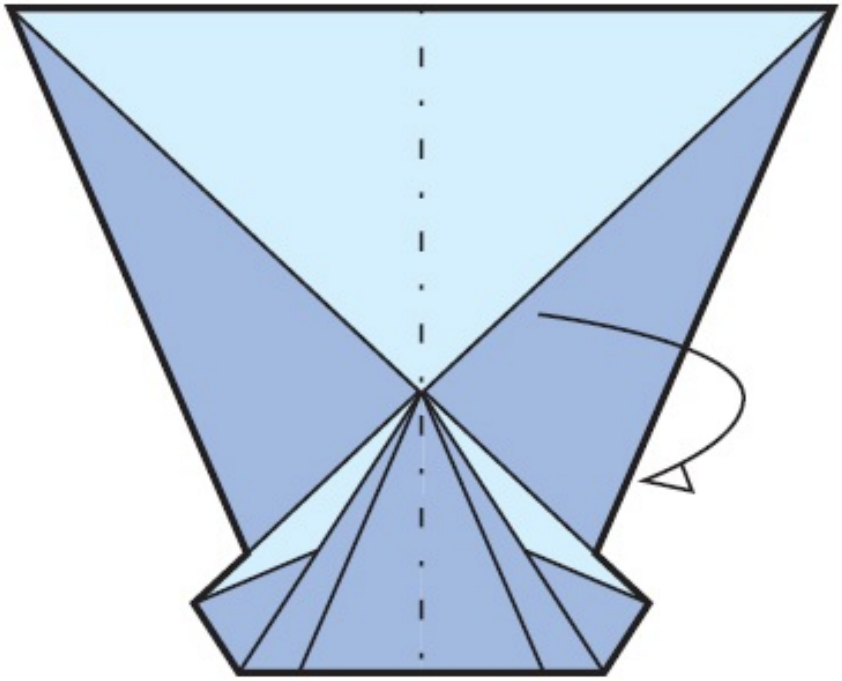
4 Crease the pocket flat along the 5 lines.



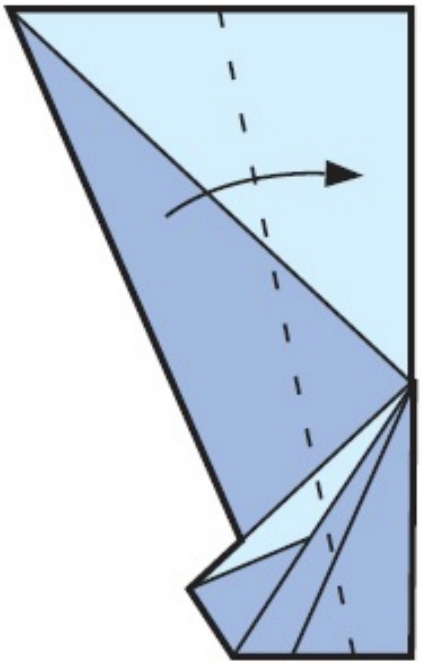
5 Fold the corners of the front wings in to the center on the 6 lines.



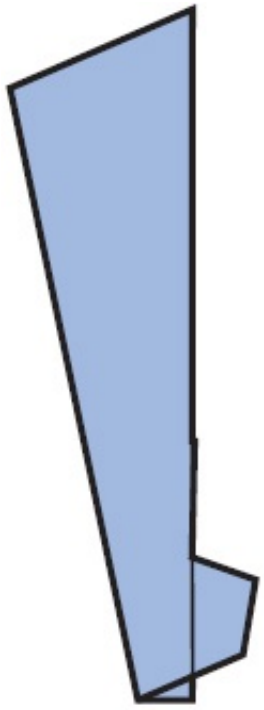
6 Fold the front up on line 7 to the point shown.



7 Fold the plane in half away from you.



8 Fold the wings down on the 8 lines, so that the outer edges just meet the center line.



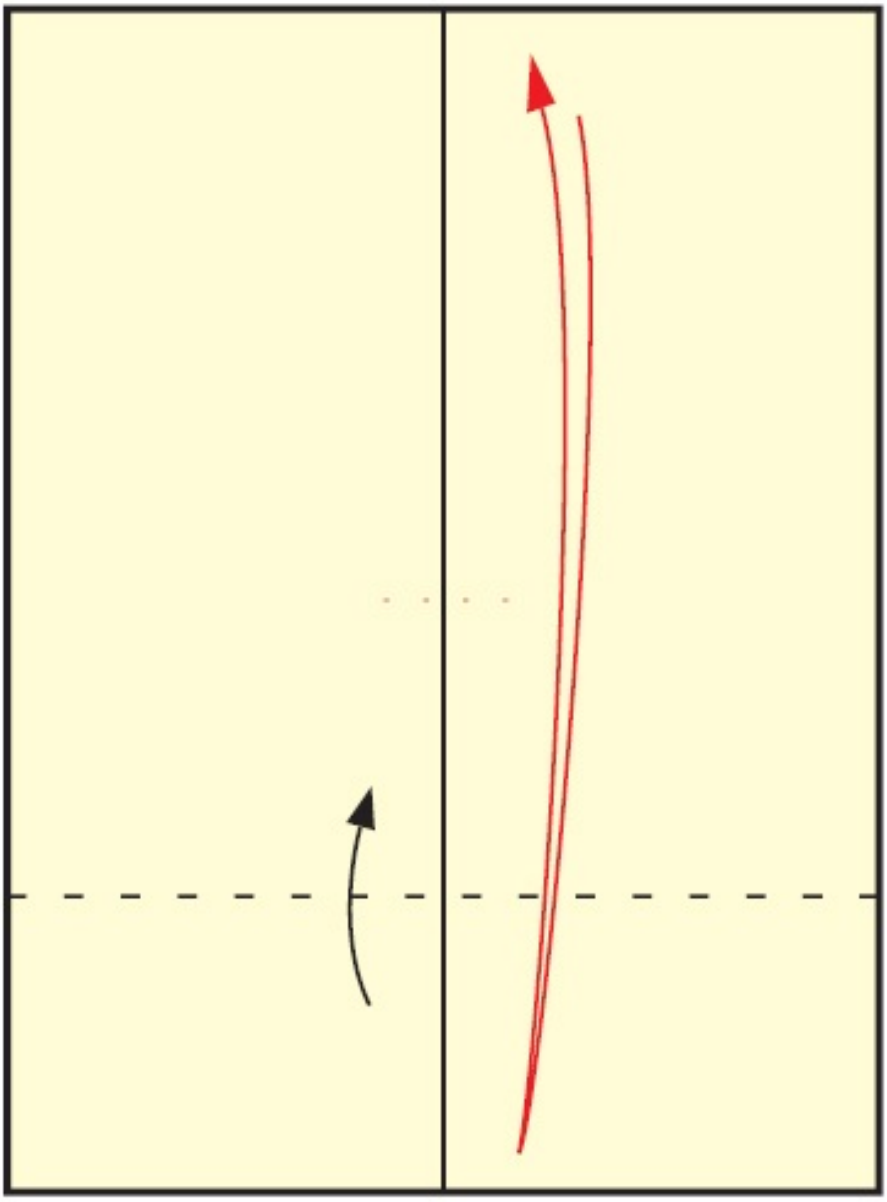
9 Open out the wings, and you're done!

Airframe Notes: The heavy nose gives good momentum, and the canard wings at the front help prevent stalls.

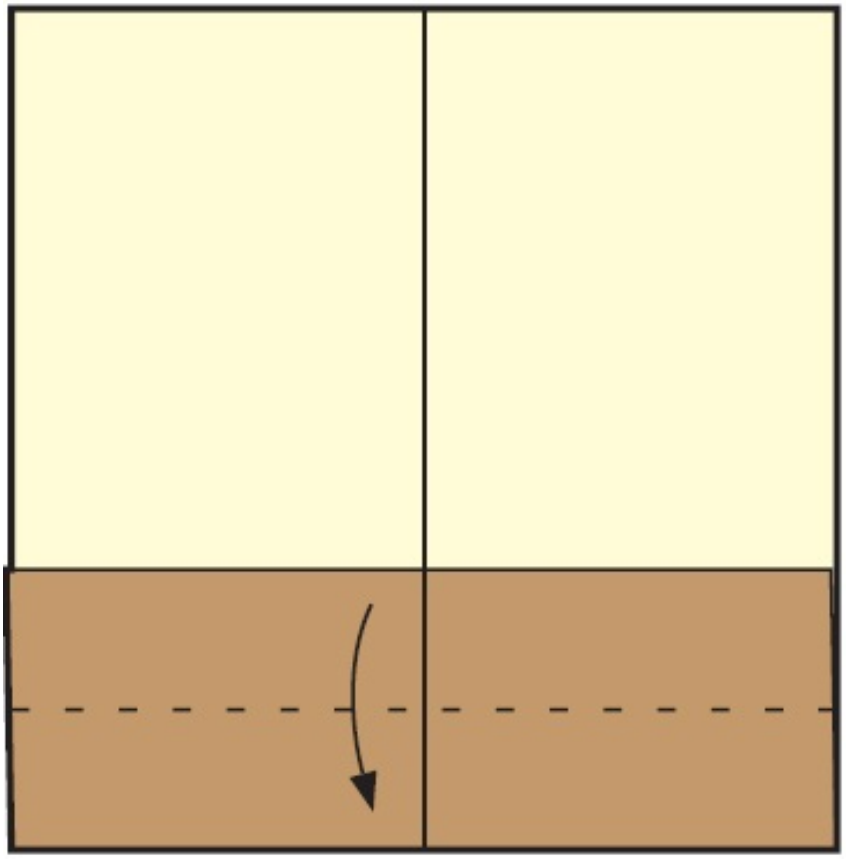
THE MATRIX

Long, highly swept wings are usually not very efficient for slow gliding, but they are very good when thrown hard! This plane looks a little delicate, but in flight it goes like a rocket. In a word, stellar!

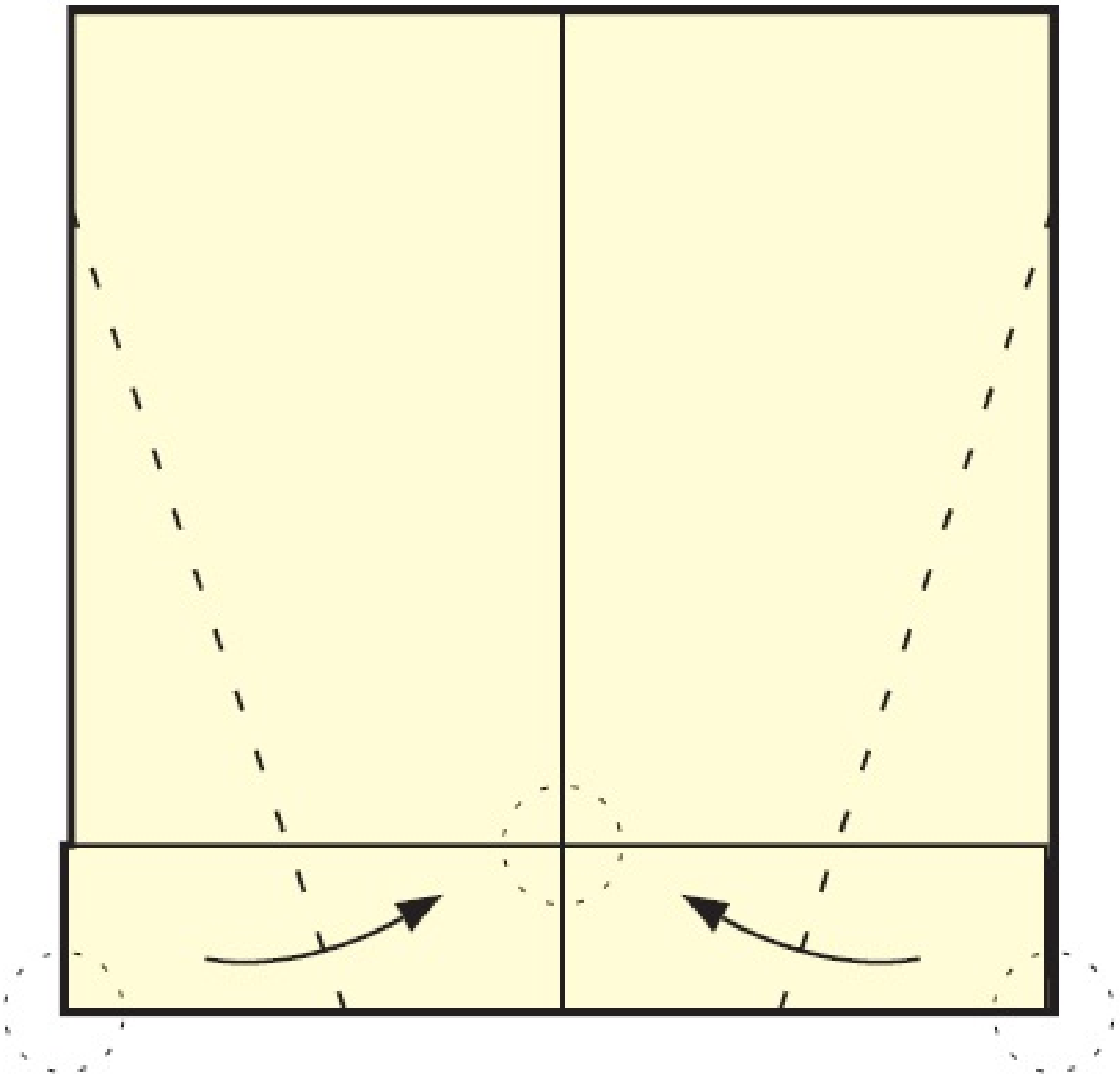
Author's Average
Distance Flown: 41 Yards



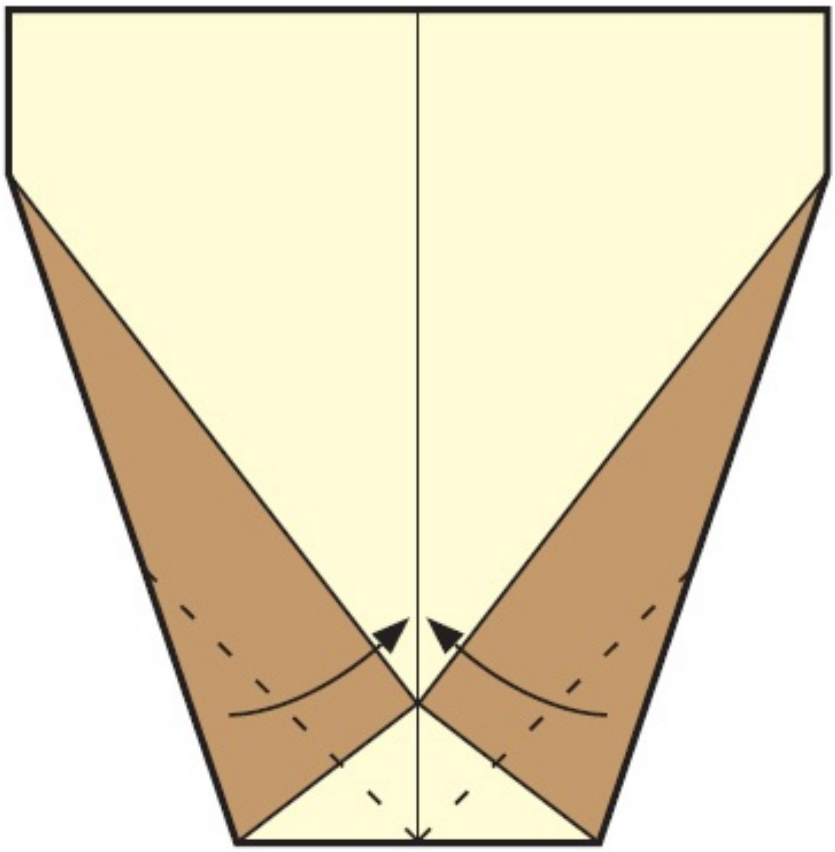
1 Start with the paper face down. Fold the bottom edge up to the center of the paper on line 1.



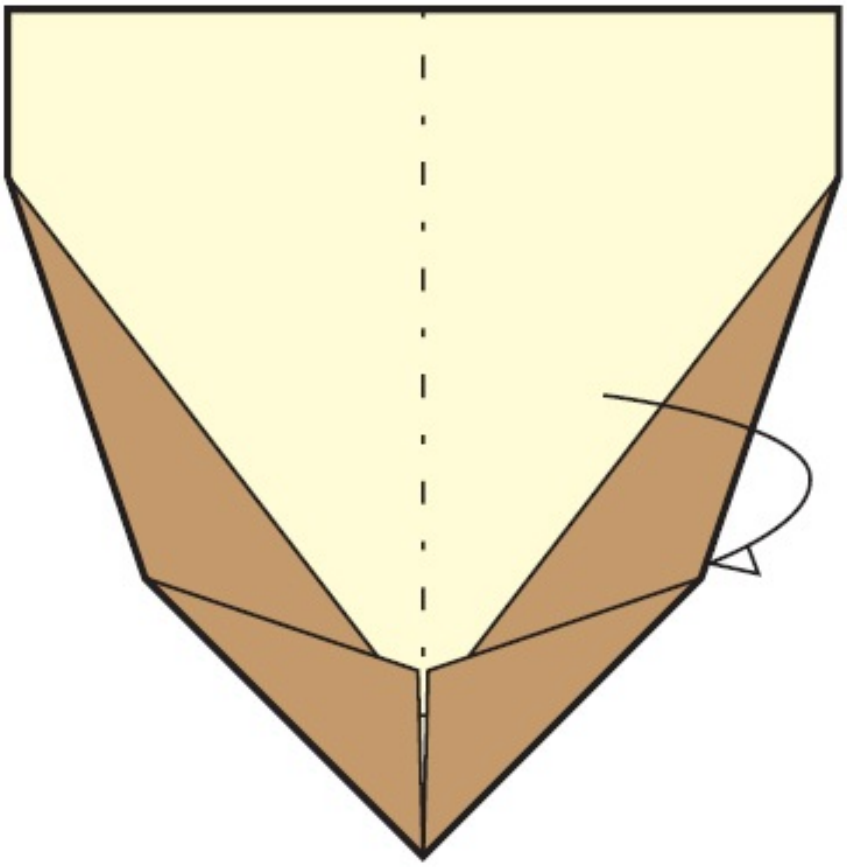
2 Fold that same edge back down to the new bottom on line 2.



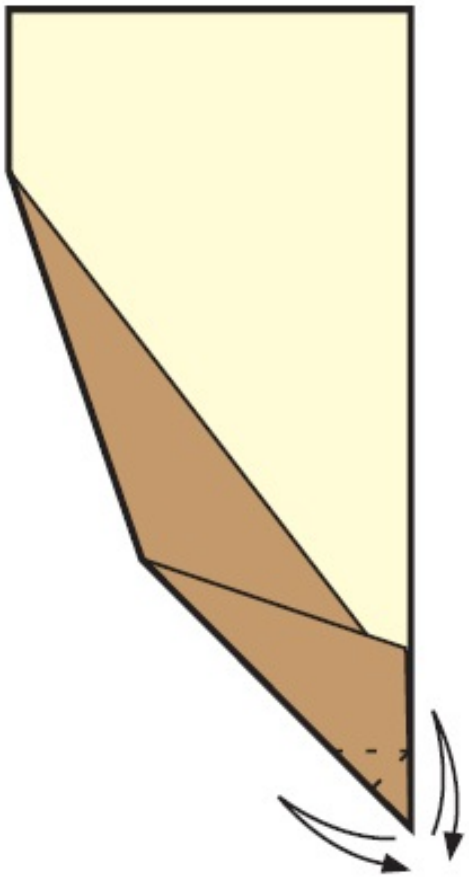
3 Fold the bottom corners on the 3 lines so that they meet at the point shown.



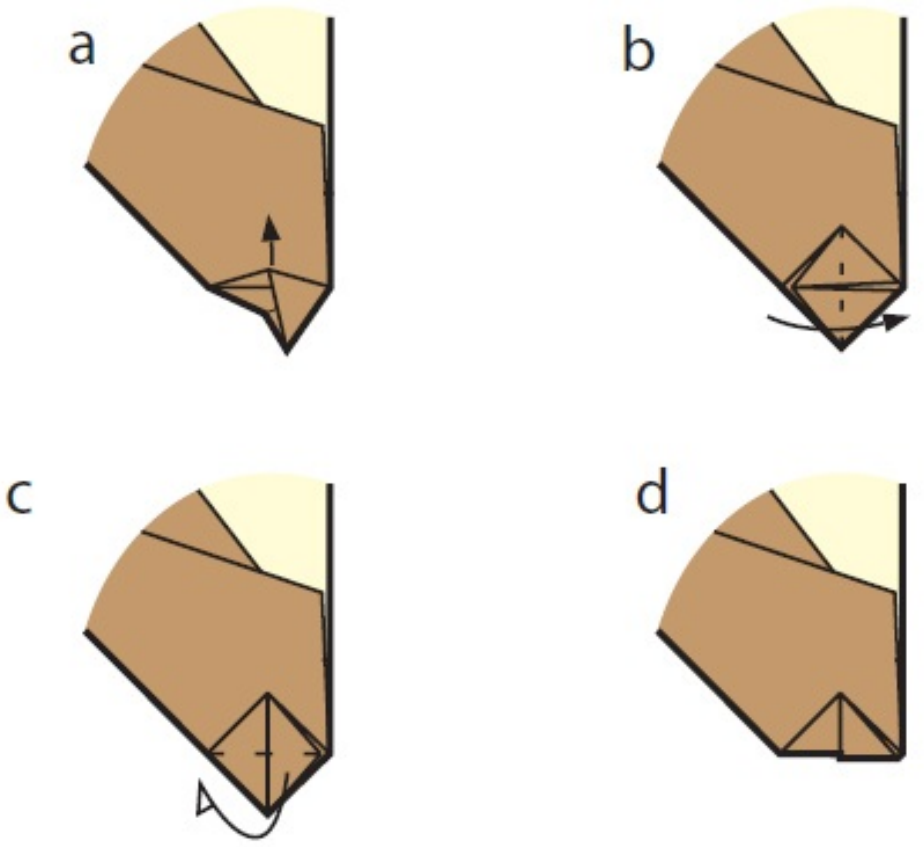
4 Fold the bottom corners again on the 4 lines, so the bottom edge meets the center line.



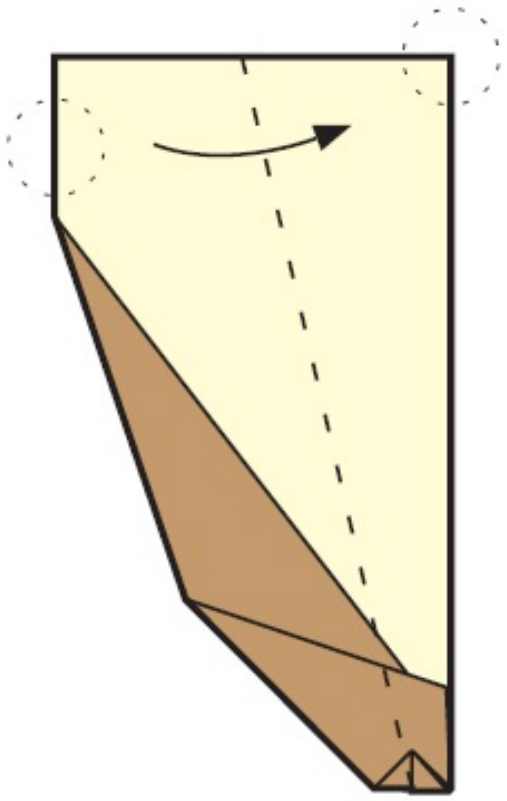
5 Fold the plane in half away from you.



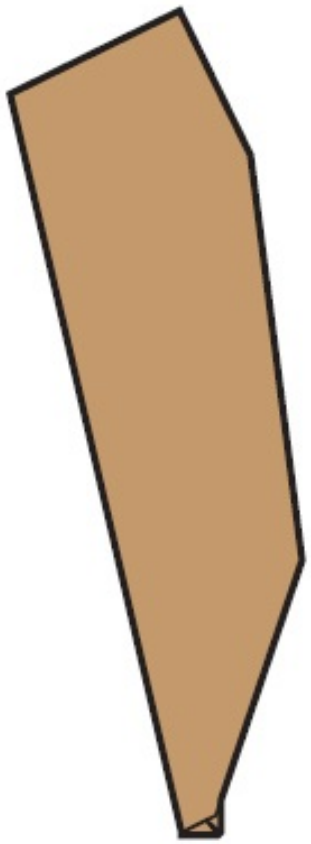
6 Fold and unfold on lines 5 and 6. The crease at 4 starts where the paper gets thick under the folded edges.



7 Pull the top layer of the nose up and fold it right back over. The bottom right corner will flip up and flatten on the 6 lines. Fold the tip down on line 7, and then fold the lower layer to the other side.



8 Fold the wings down on the 8 lines, starting from the center of the nose. The outer edge of the wing should just touch the corner of the fuselage.

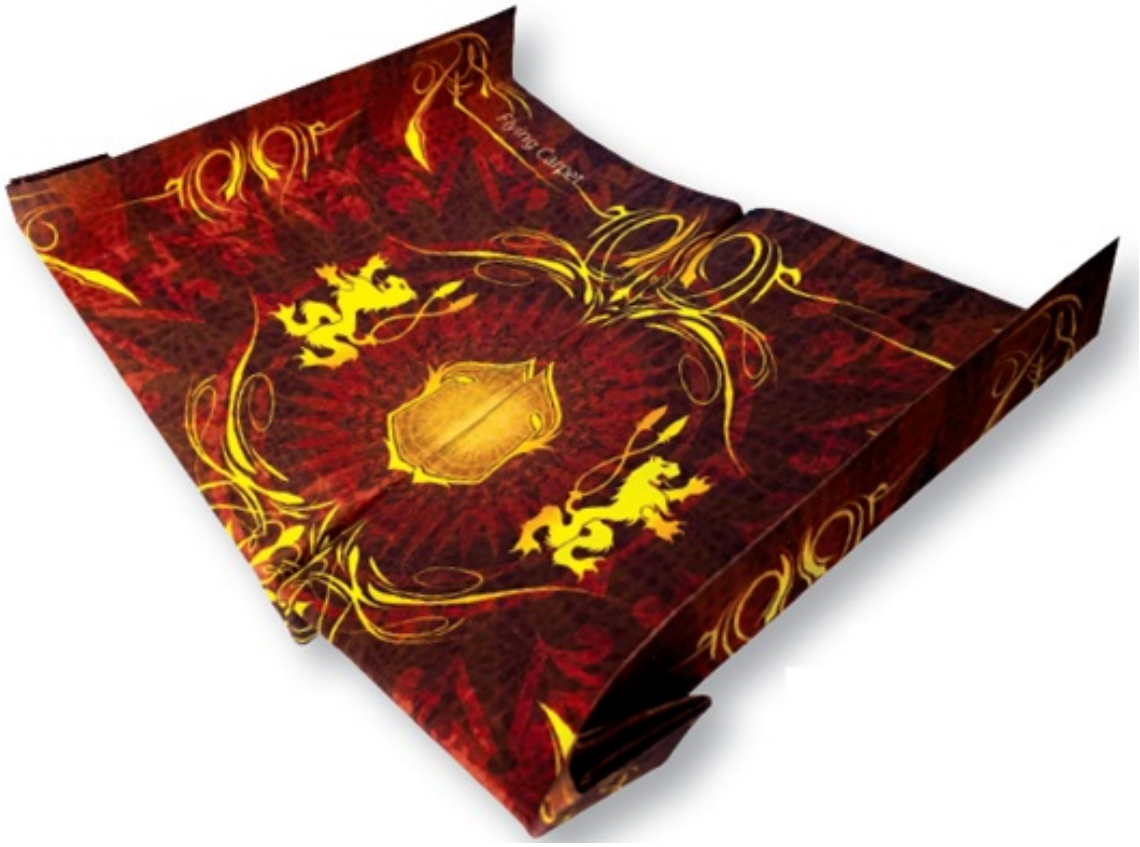


9 Straighten out the wings, and you're ready to go!

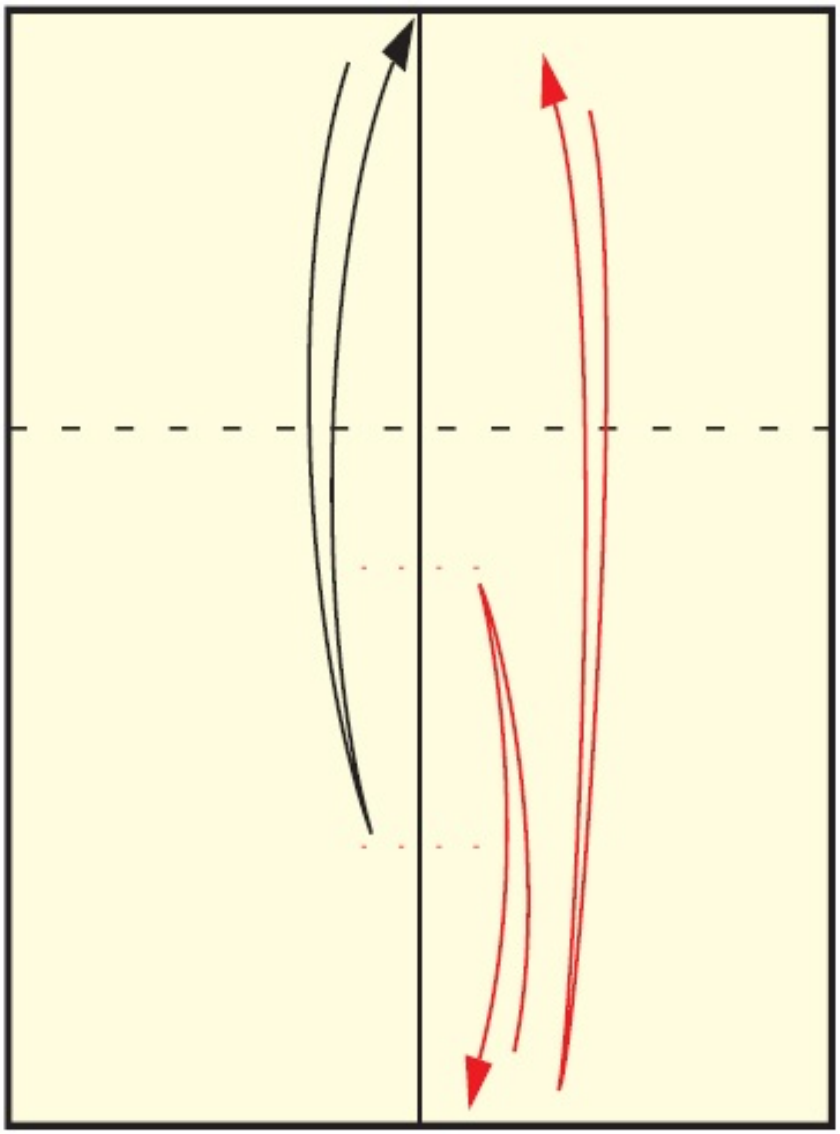
Airframe Notes: Stiff enough for strong throws, but with enough wing area for a gentle, flat glide after the initial speed wears off.

THE FLYING CARPET

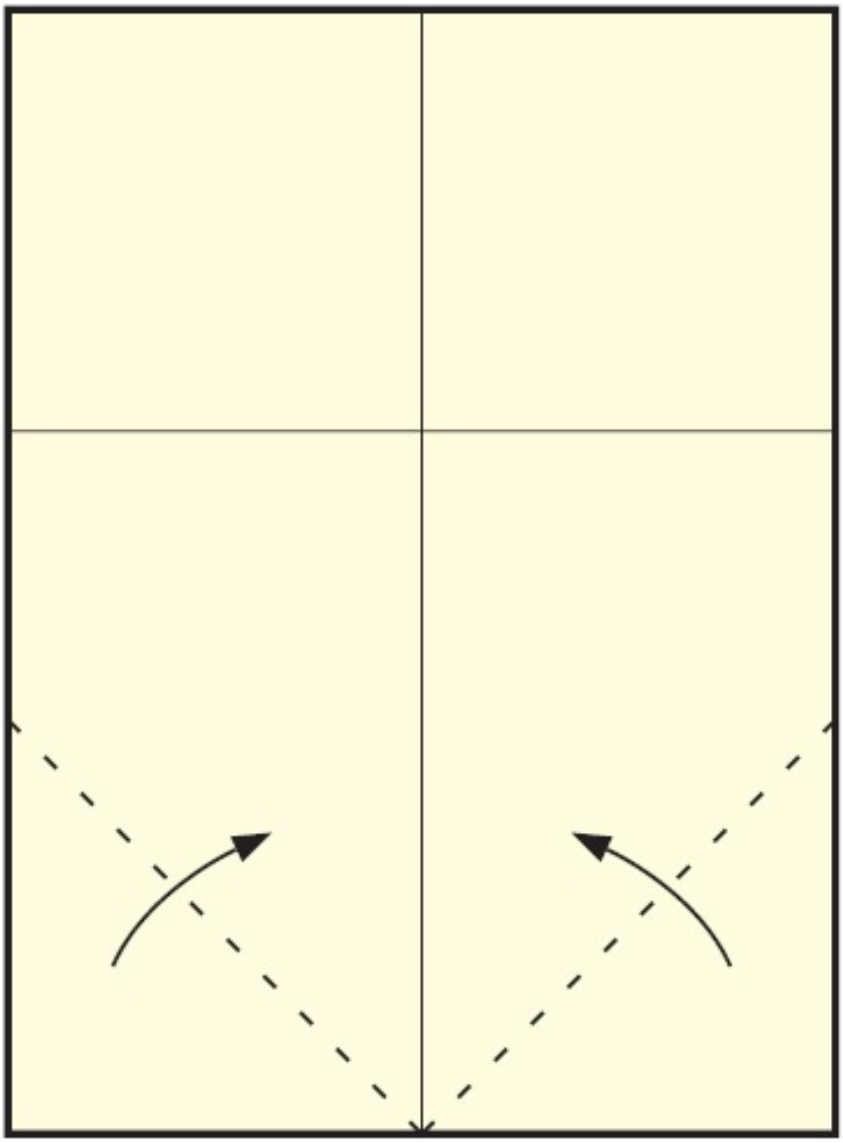
The square shape and wingtip fins of this plane make it look more like a carpet than an airplane. But this is a flying carpet, drifting around high overhead as if held up by magic!



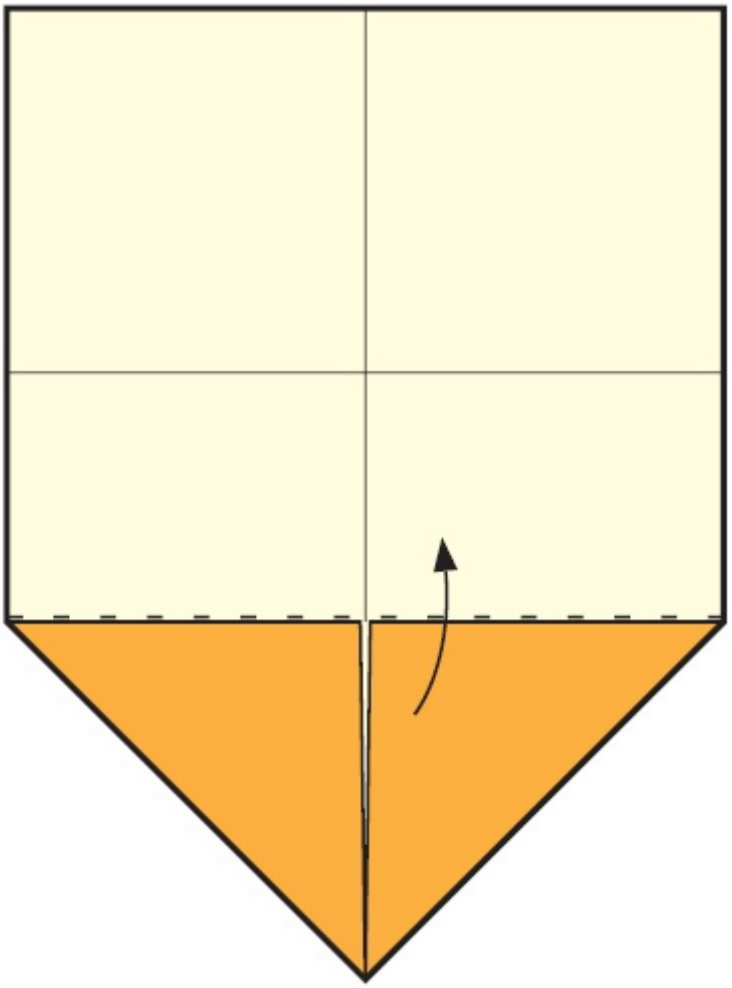
Author's Average Time
Aloft: 14 Seconds



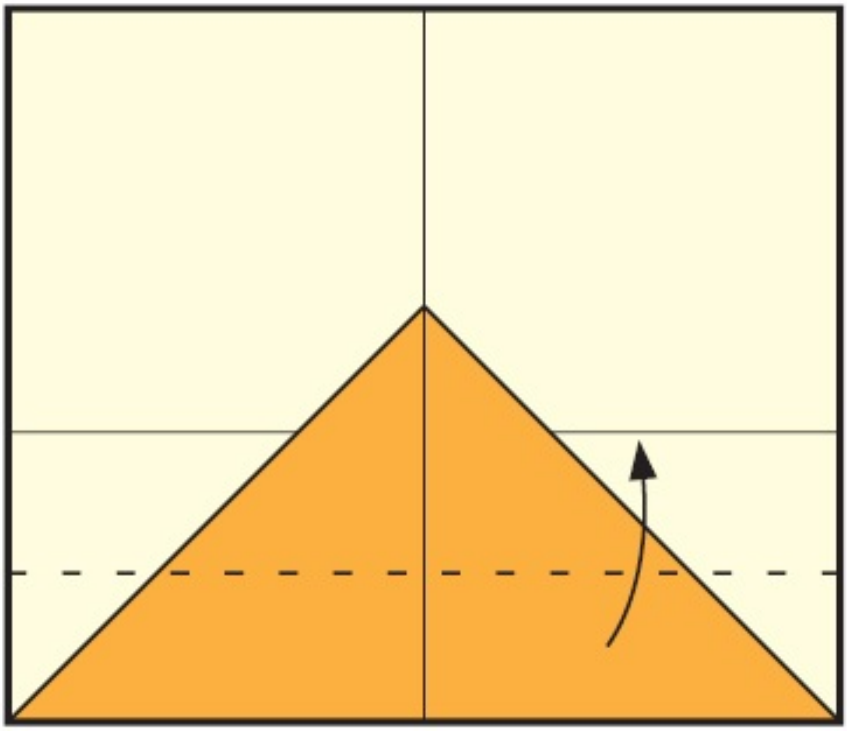
1 Start with the paper face down. Fold and unfold line 1. The red arrows show how to find where to make the fold.



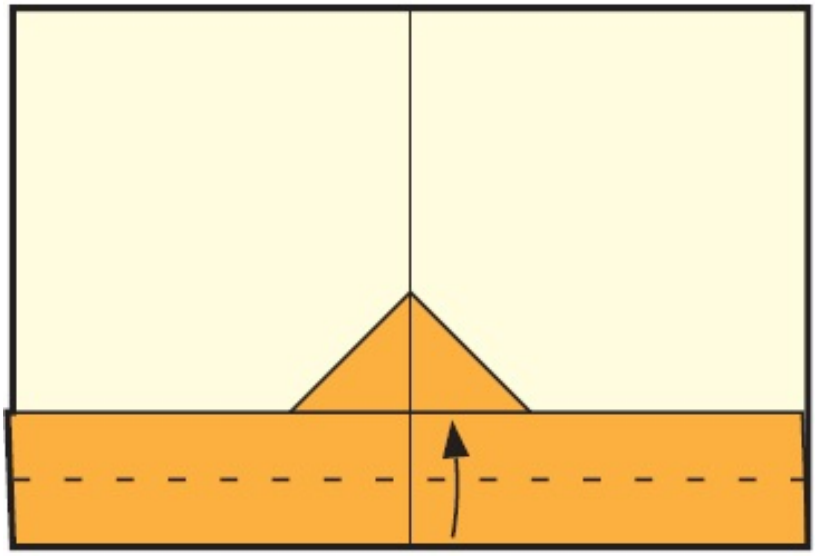
2 Fold the bottom corners up to the center line on the 2 lines.



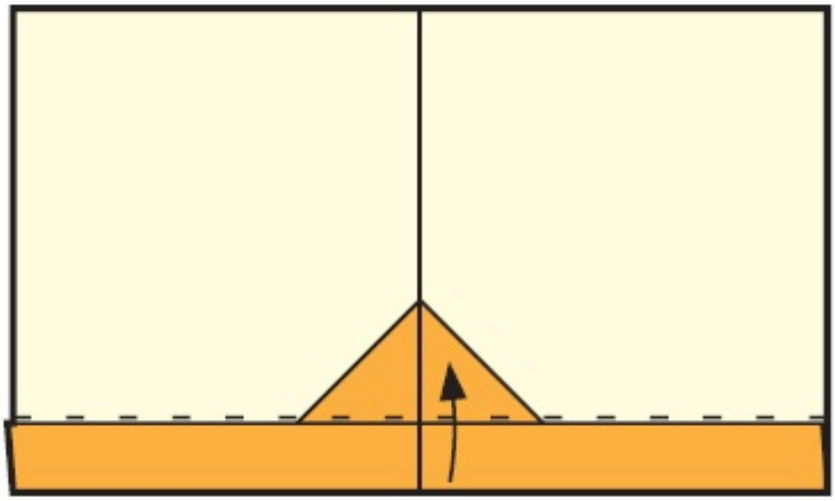
3 Fold the tip of the paper up on line 3.



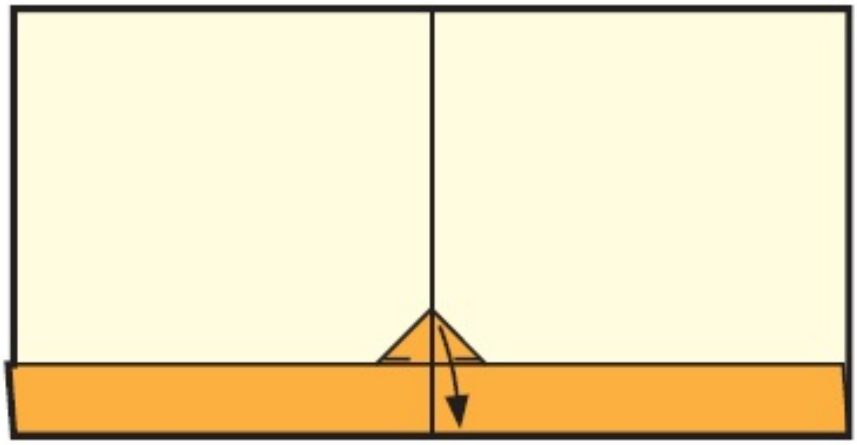
4 Fold the bottom edge of the paper up on line 4 to meet the crease at line 1.



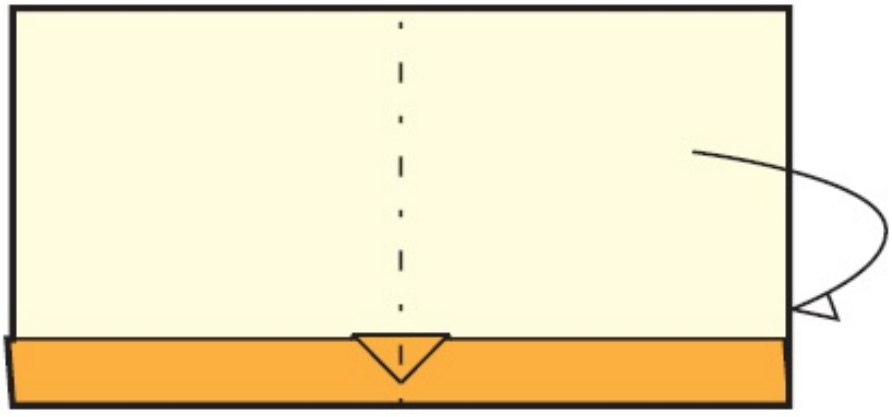
5 Fold up again on line 5.



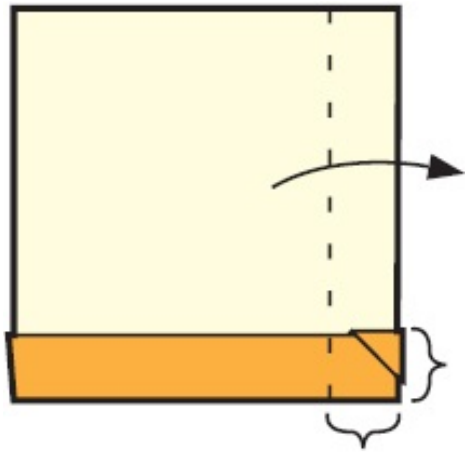
6 Refold line 1.



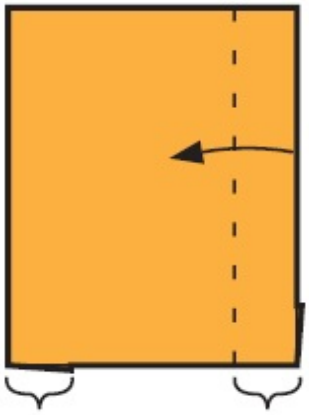
7 Fold the loose tip down on line 6.



8 Fold the plane in half away from you.



9 Fold the wings down on the 7 lines.



10 Fold the wingtips up on the 8 lines.

11 Open out and trim the wings and wingtip fins so that they look like this when seen

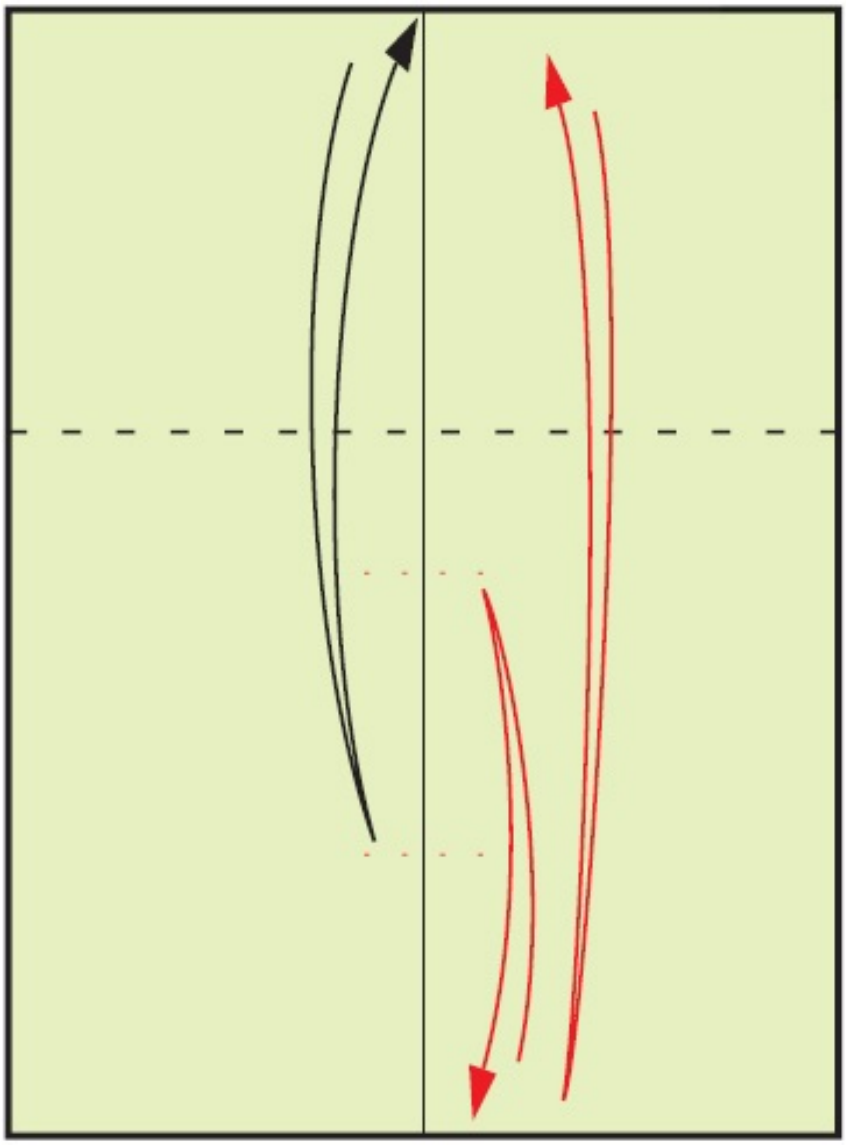
from the front.

Airframe Note: Needs occasional adjustment to avoid twisting.

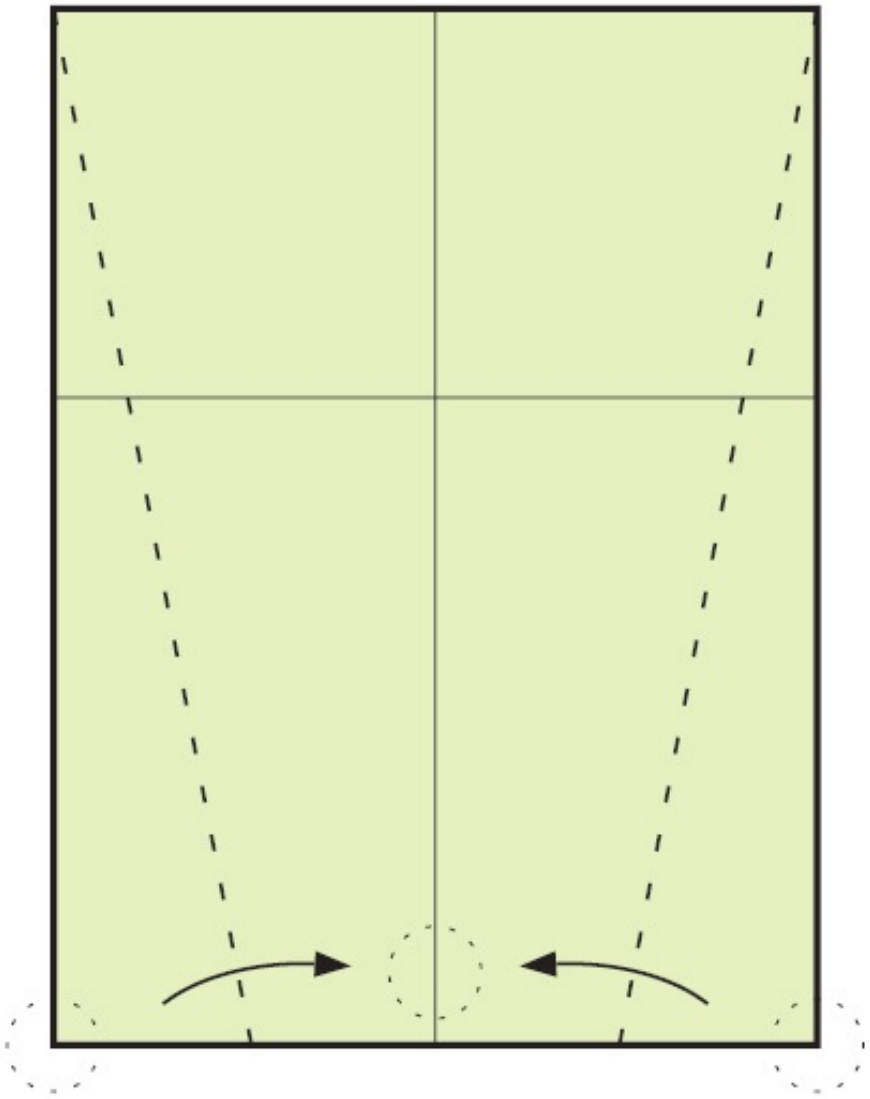
THE CONDOR

This plane looks a lot like Ken Blackburn's record-breaking airplane, but except for the diagonal side folds, it is a quite different design. The name comes from the world's biggest bird of prey, the 3-yard-wide condor of the Andes.

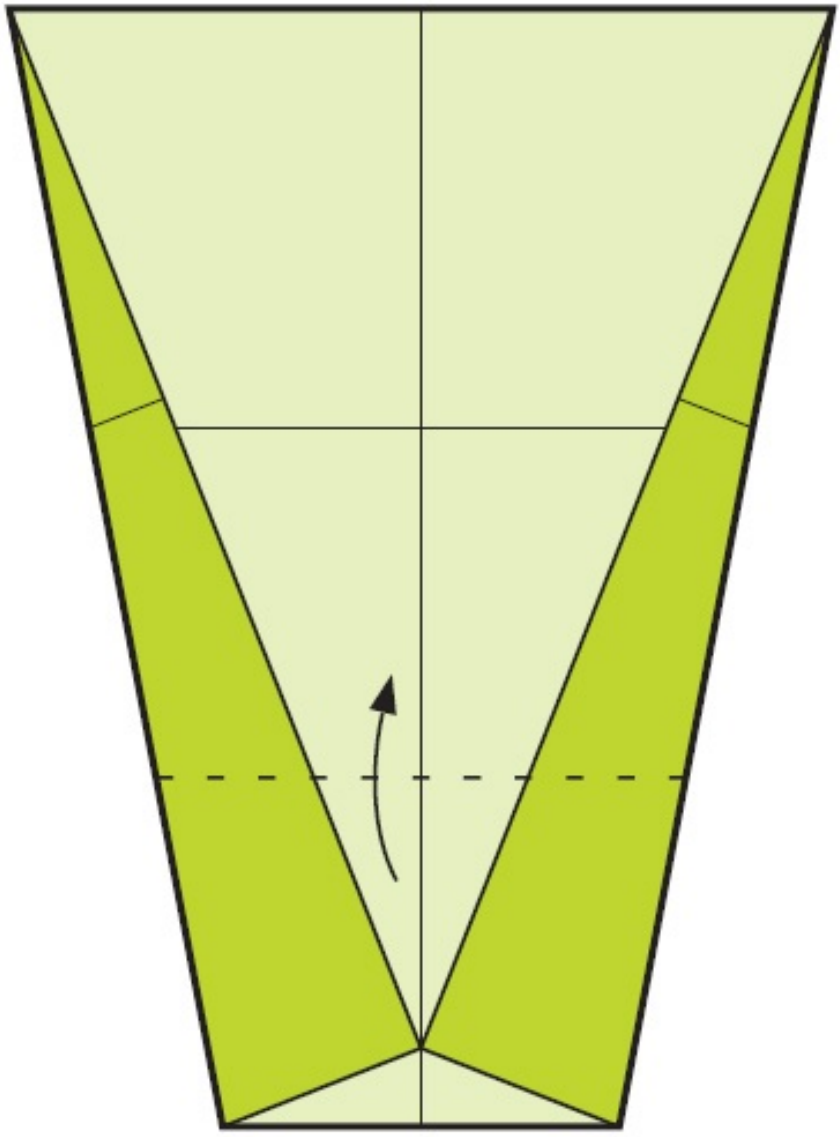
Author's Average
Time Aloft: 16 Seconds



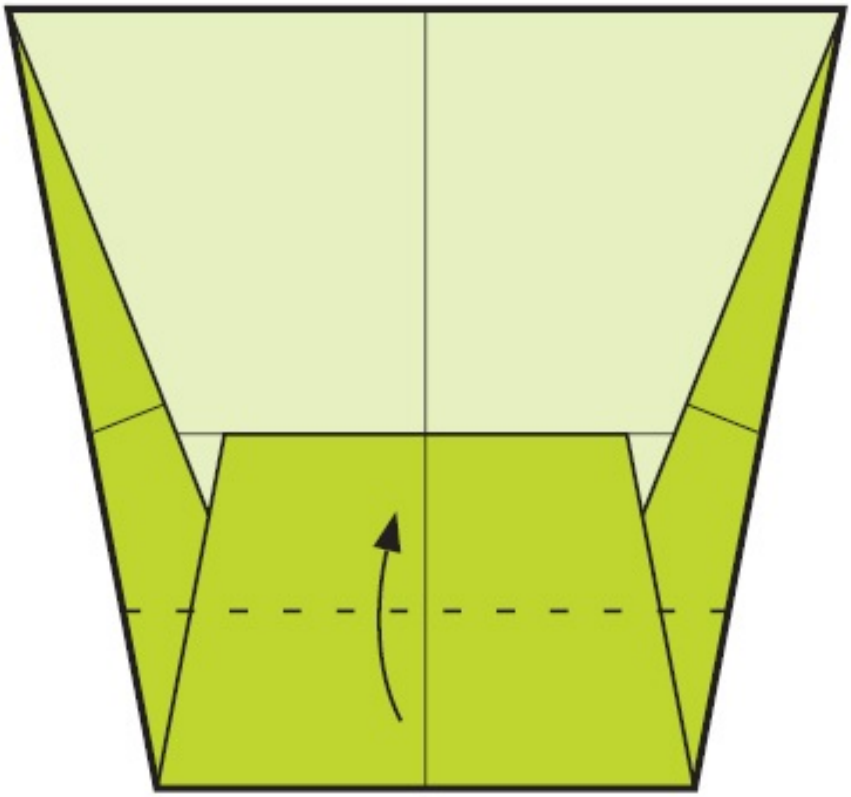
1 Start with the paper face down. Fold and unfold line 1. The red arrows show how to find where to make the fold.



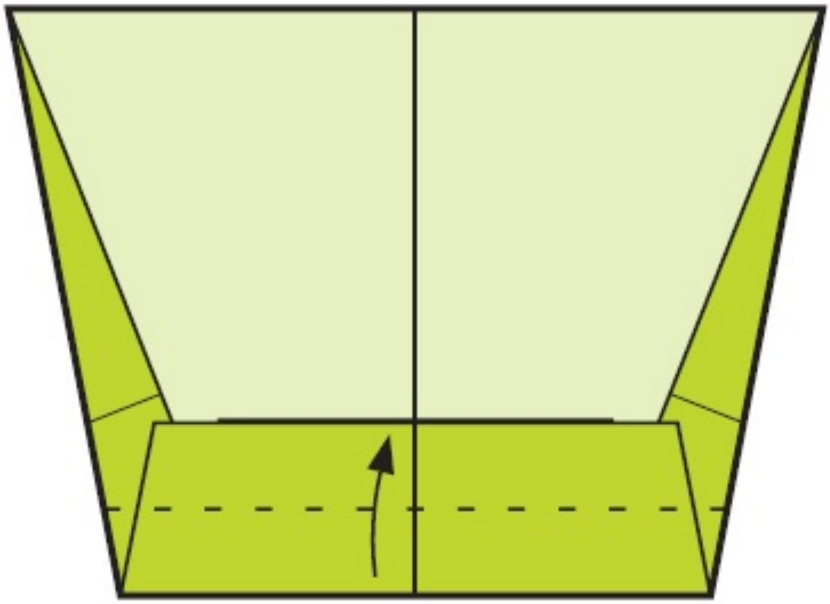
2 Fold the bottom corners on the 2 lines so they just meet at the center line.



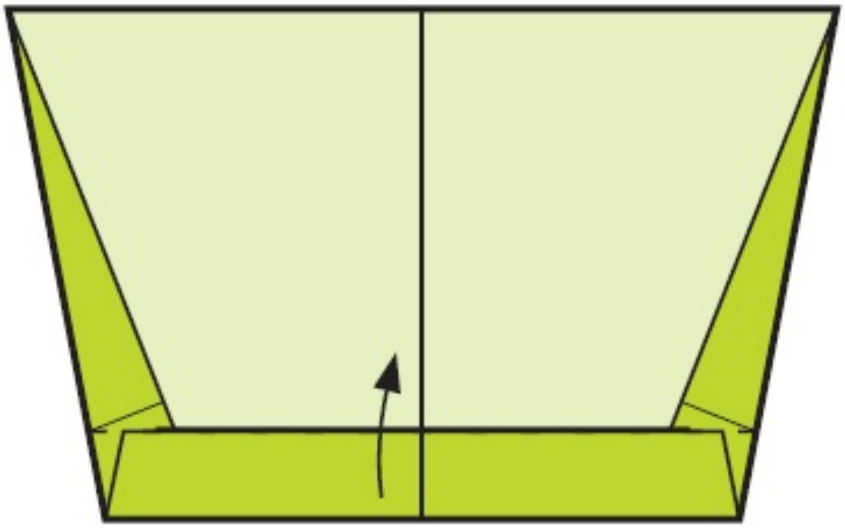
3 Fold up on line 3 so the bottom edge of the paper meets the crease at line 1.



4 Fold the bottom up again on line 4.

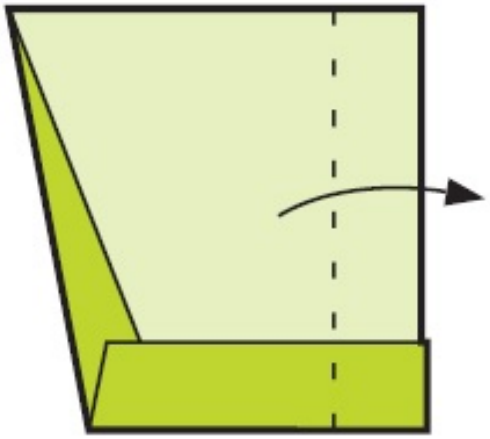


5 Fold up again on line 5.

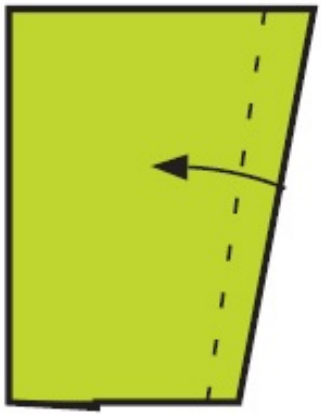


6 Refold line 1.

7 Fold the plane in half away from you.



8 Fold the wings down on the 6 lines.



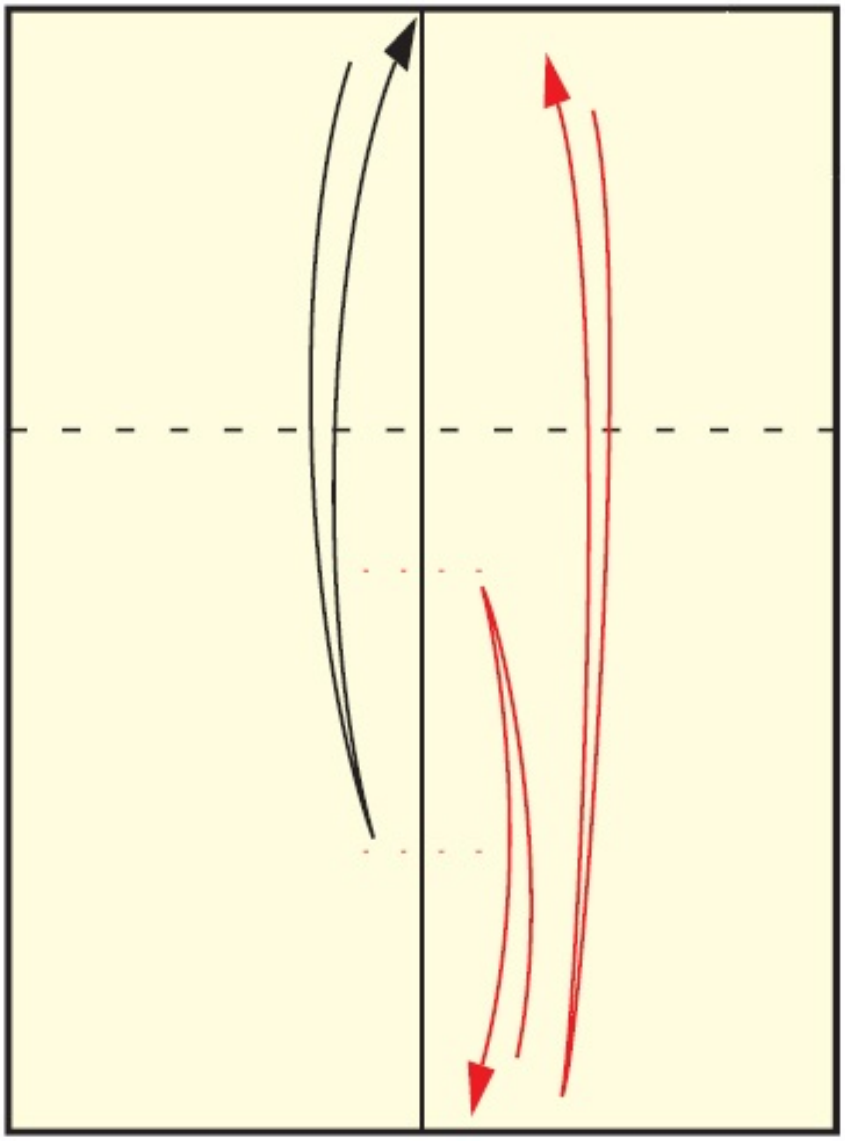
9 Fold the wingtips up on the 7 lines.

10 Straighten the wings and wingtips so they look like this when seen from the front.

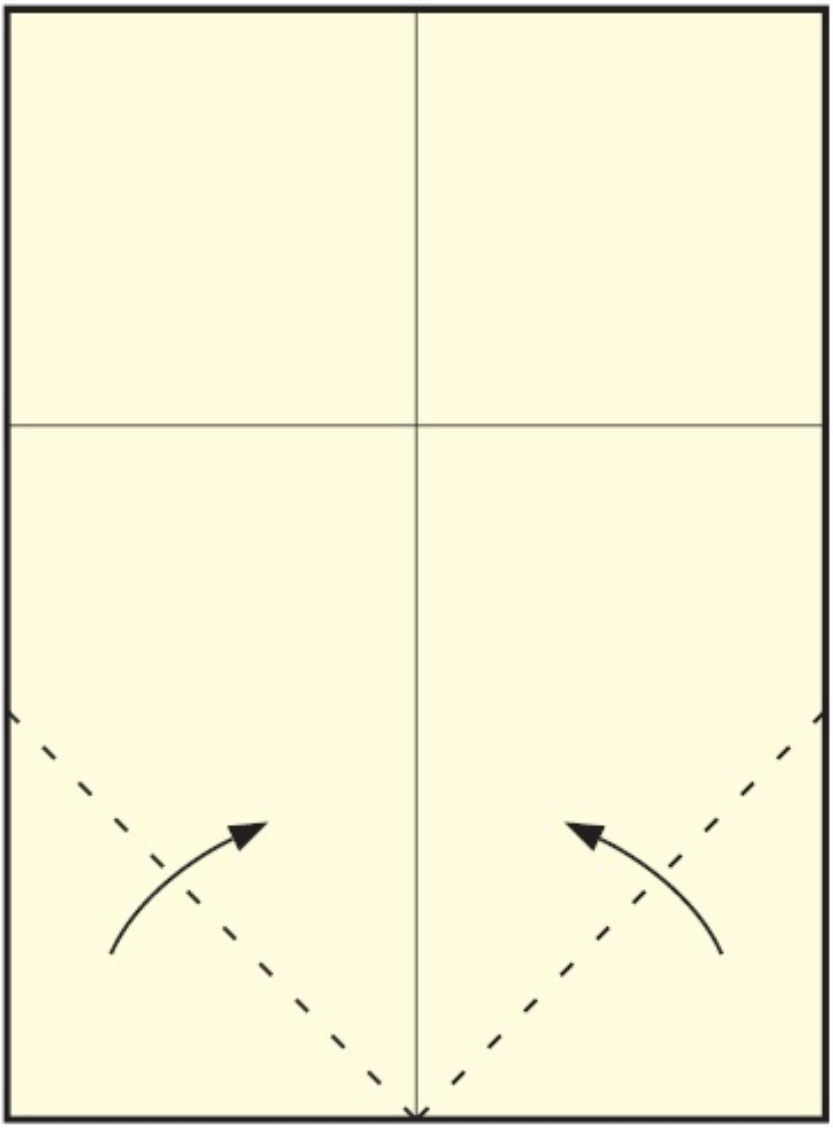
THE FALCON

If condors are the world's largest flying birds, falcons are the fastest. Long, pointed wings and powerful muscles mean they can swoop and dive at race car speeds. How fast can you fly the Falcon?

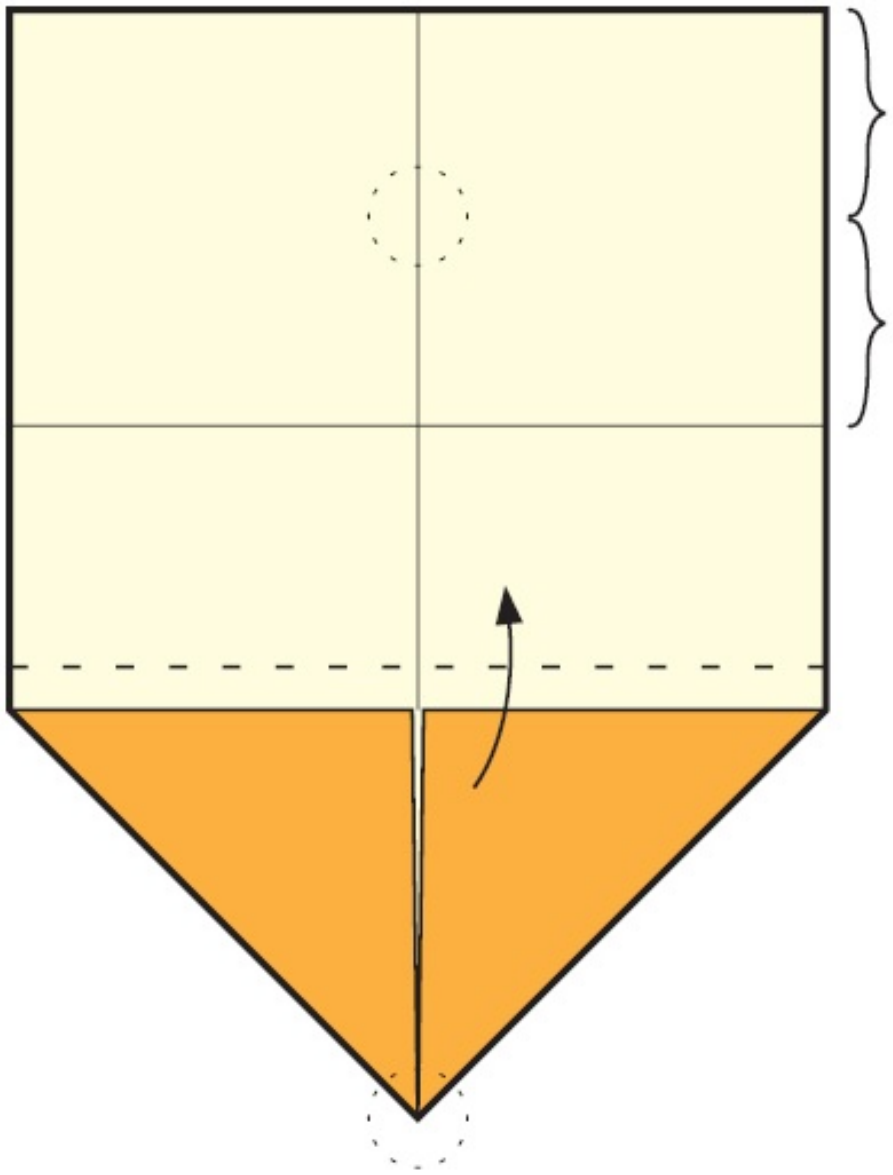
Author's Average Time
Aloft: 17 Seconds



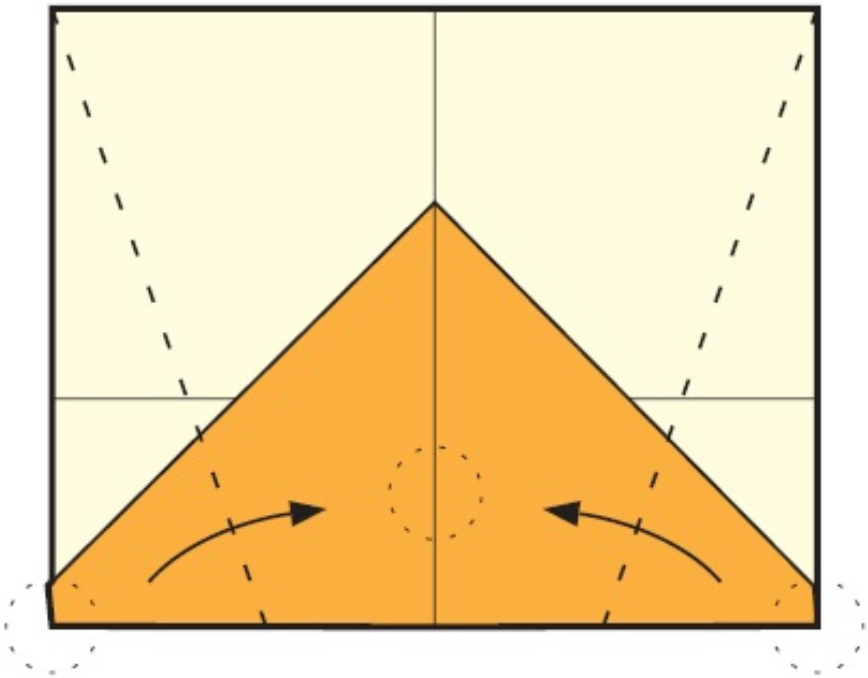
1 Start with the paper face down. Fold and unfold line 1. The red arrows show how to find where to make the fold.



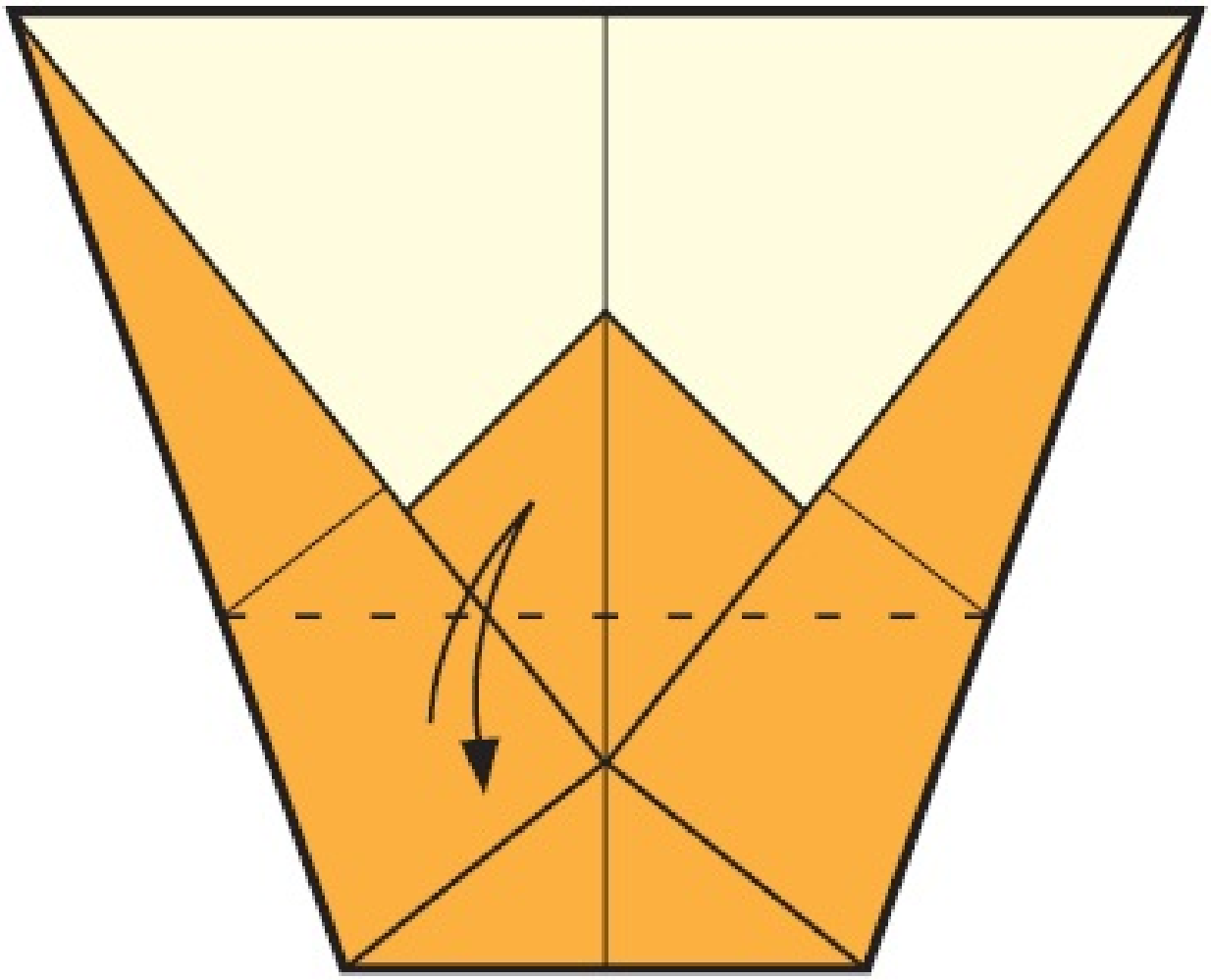
2 Fold the bottom corners up to the center line on the 2 lines.



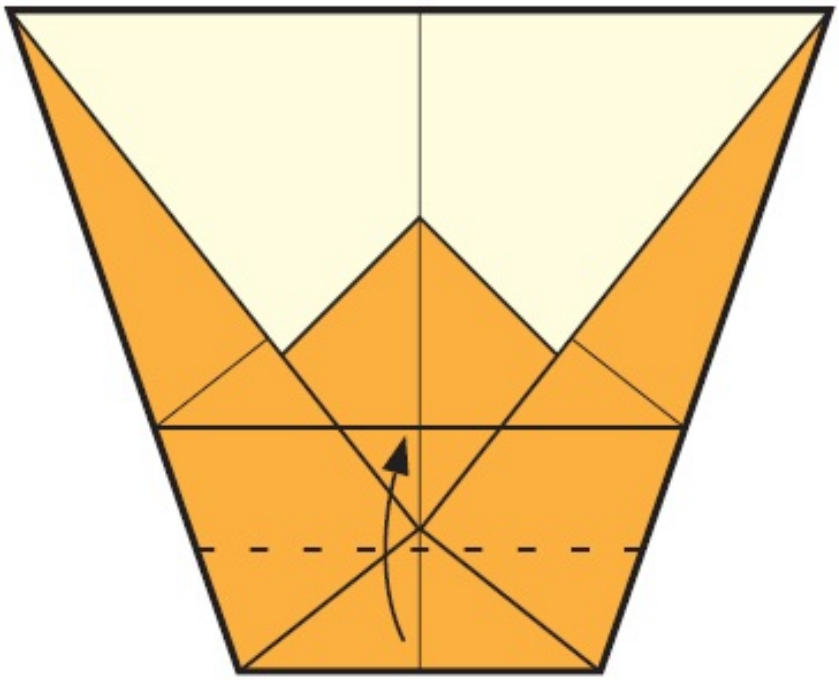
3 Fold the tip of the paper up on line 3.



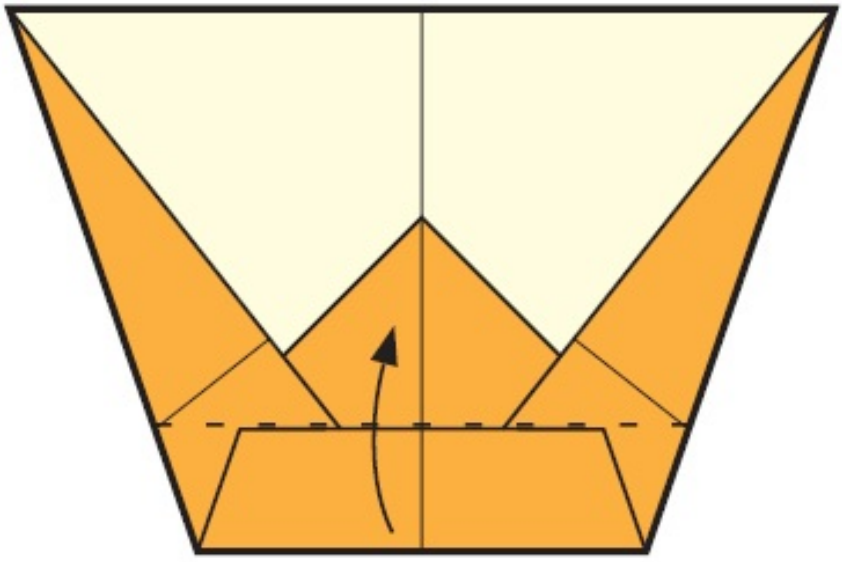
4 Fold the bottom corners in on the 4 lines so that they touch the center line as shown.



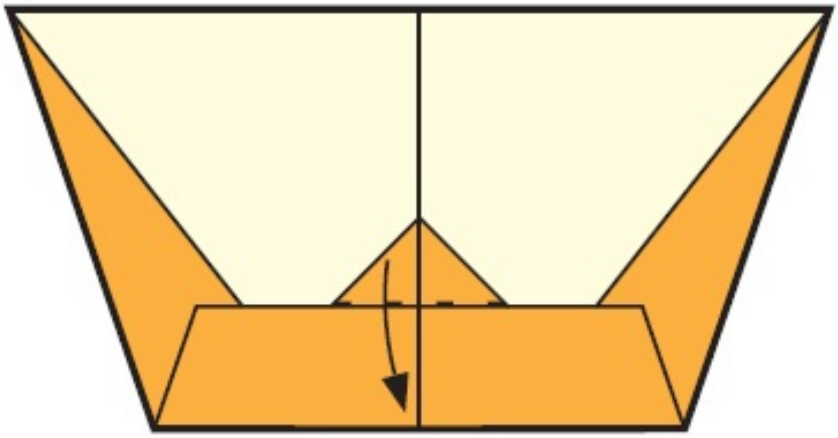
5 Fold and unfold on line 5, which starts where the creases from line 1 meet the edge of the paper.



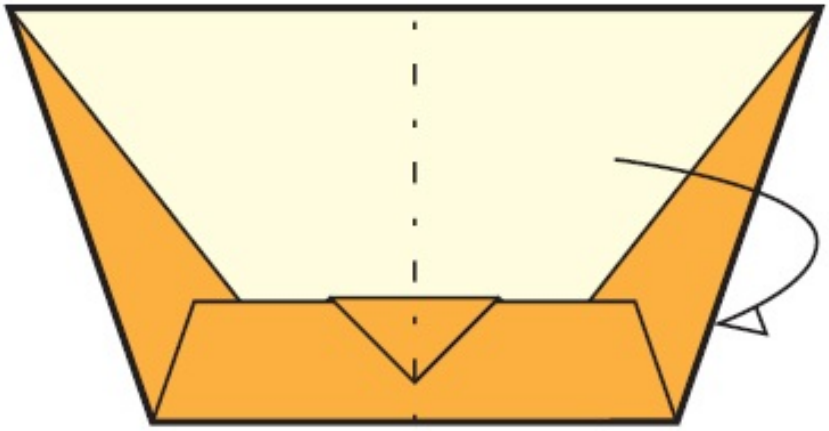
6 Fold up on line 6, so the bottom edge meets the crease at line 5.



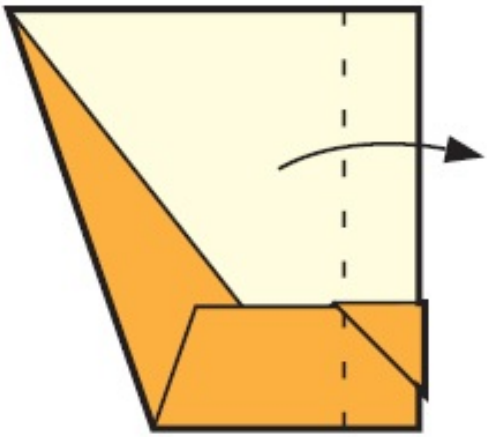
7 Refold line 5.



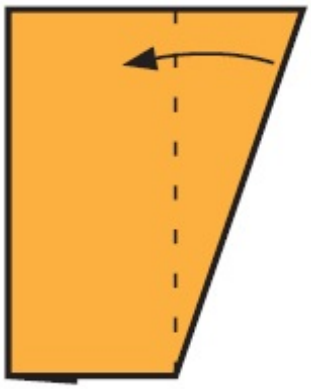
8 Fold the loose tip down on line 7.



9 Fold the plane in half away from you.



10 Fold the wings down on the 8 lines.



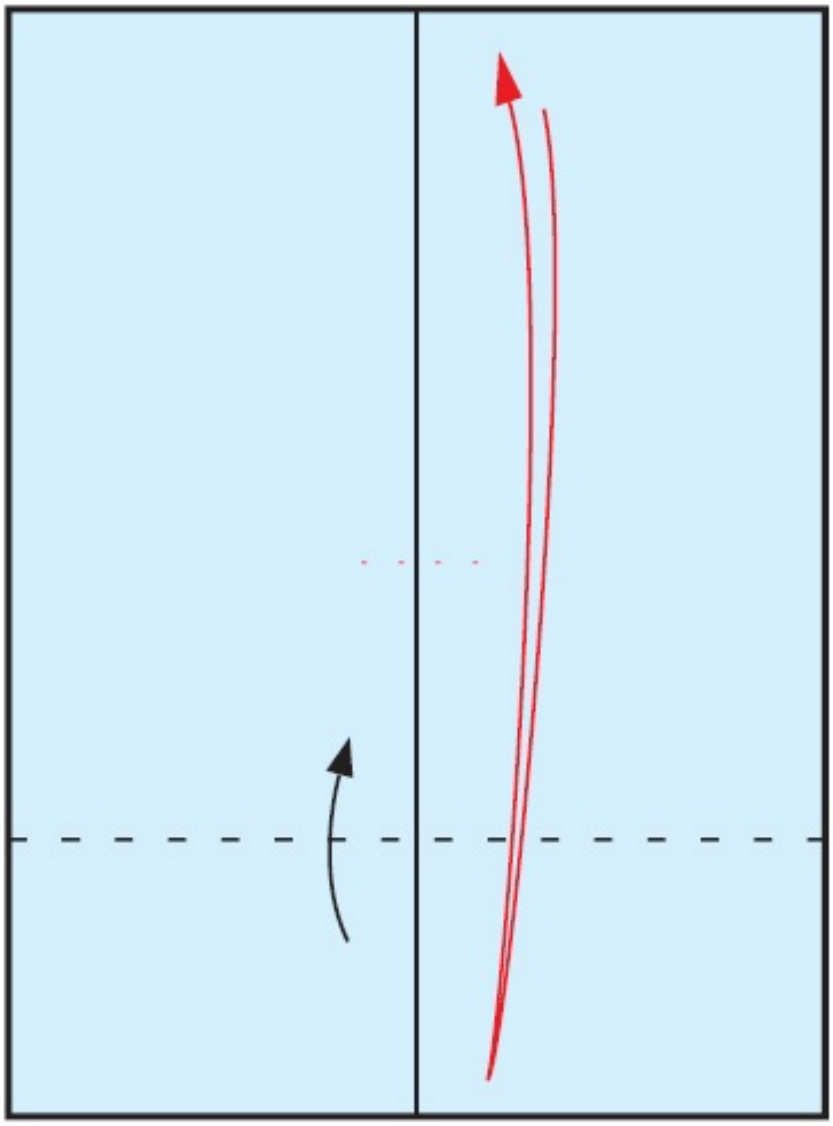
11 Fold the wingtips up on the 9 lines.

12 Pull out the wings and wingtips, and arrange them so they look like this when seen from the front. You're done!

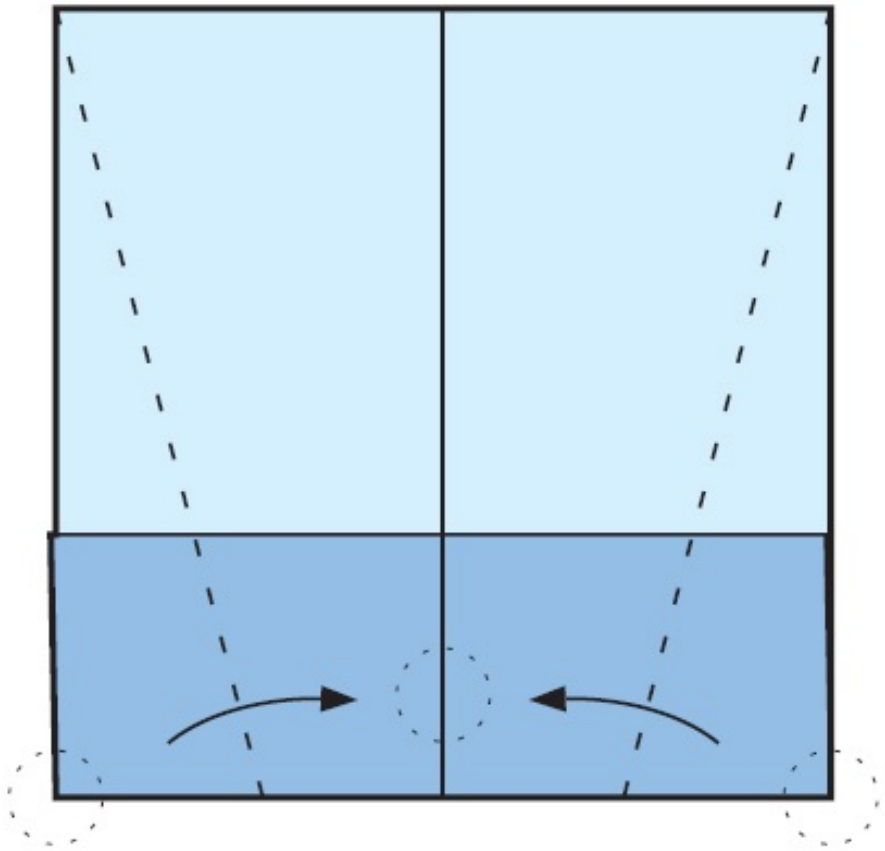
STRATUS

This plane is halfway between a dart and the broad-winged competition gliders designed by Takuo Toda. A sharp toss will send it well across a gym, in a long, flat glide.

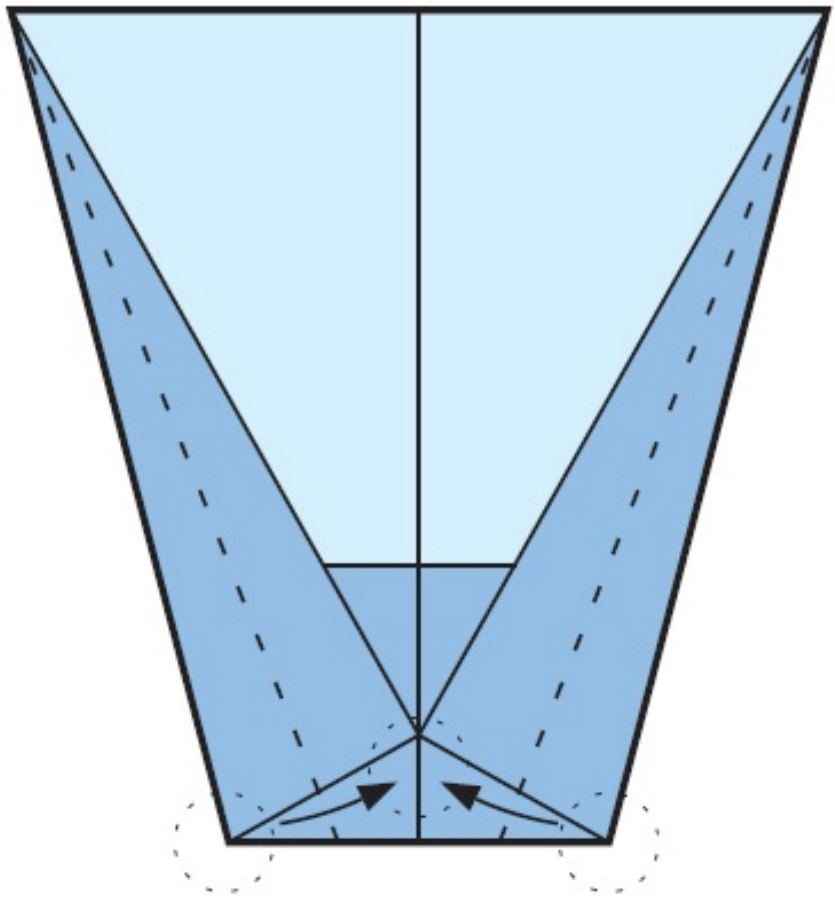
Author's Average
Time Aloft: 16 Seconds



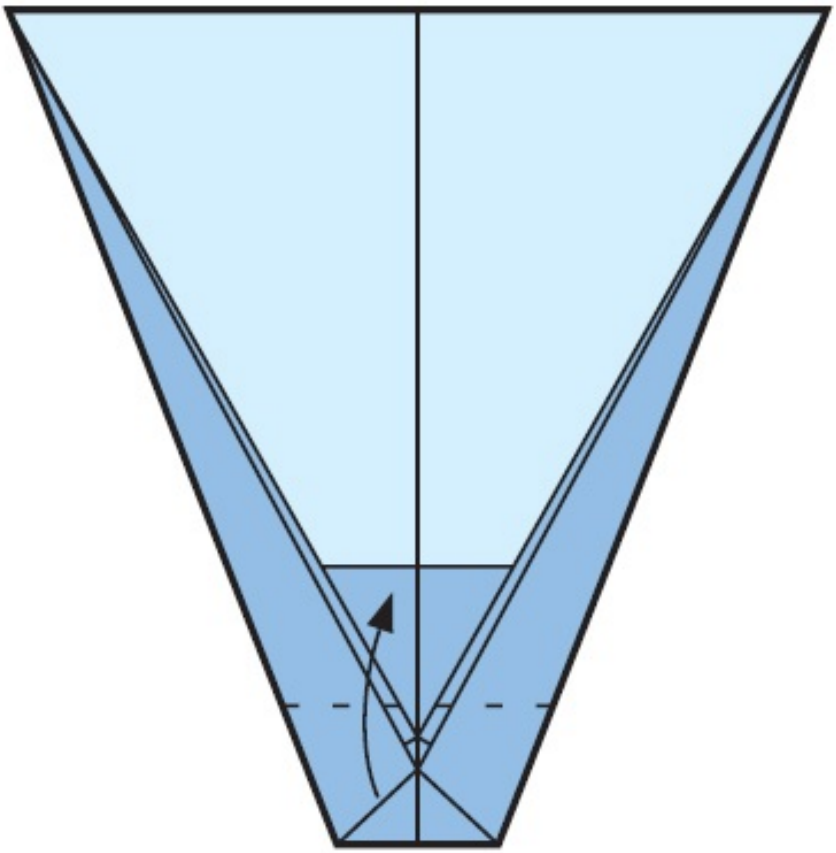
1 Start with the paper face down. Fold the bottom edge up to the center of the paper on line 1.



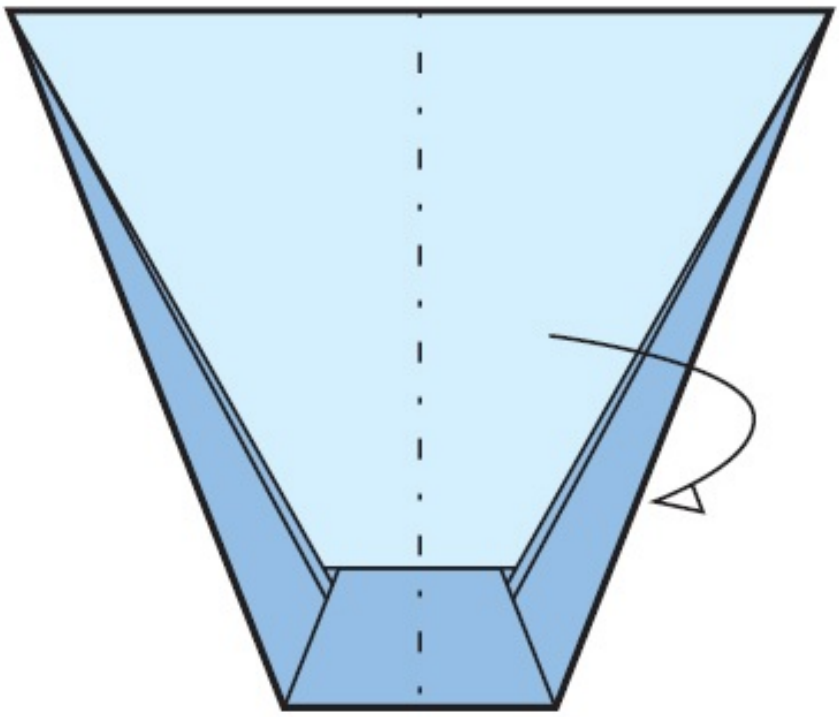
2 Fold the bottom corners in to the center line on the 2 lines as shown.



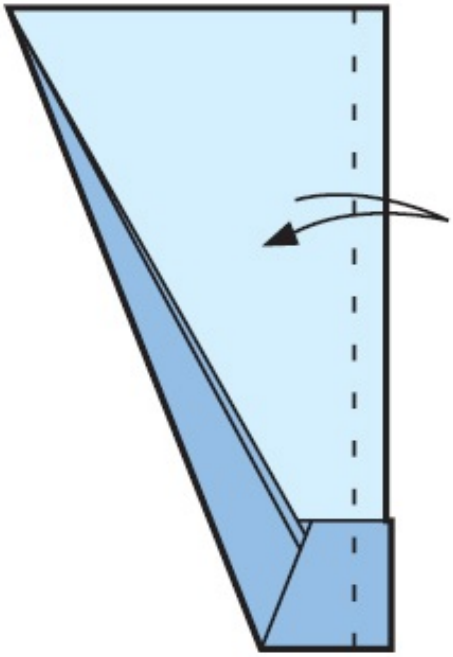
3 Fold the corners in again, the same way, on the 3 lines.



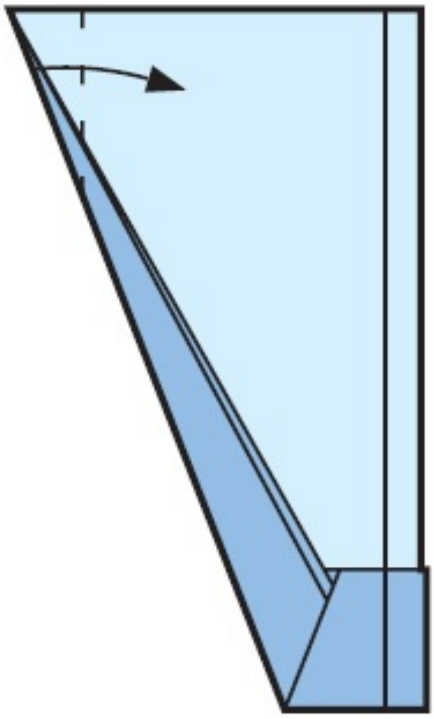
4 Fold on line 4 so the two edges meet.



5 Fold the plane in half away from you.



6 Fold and unfold the wings on the 5 lines.

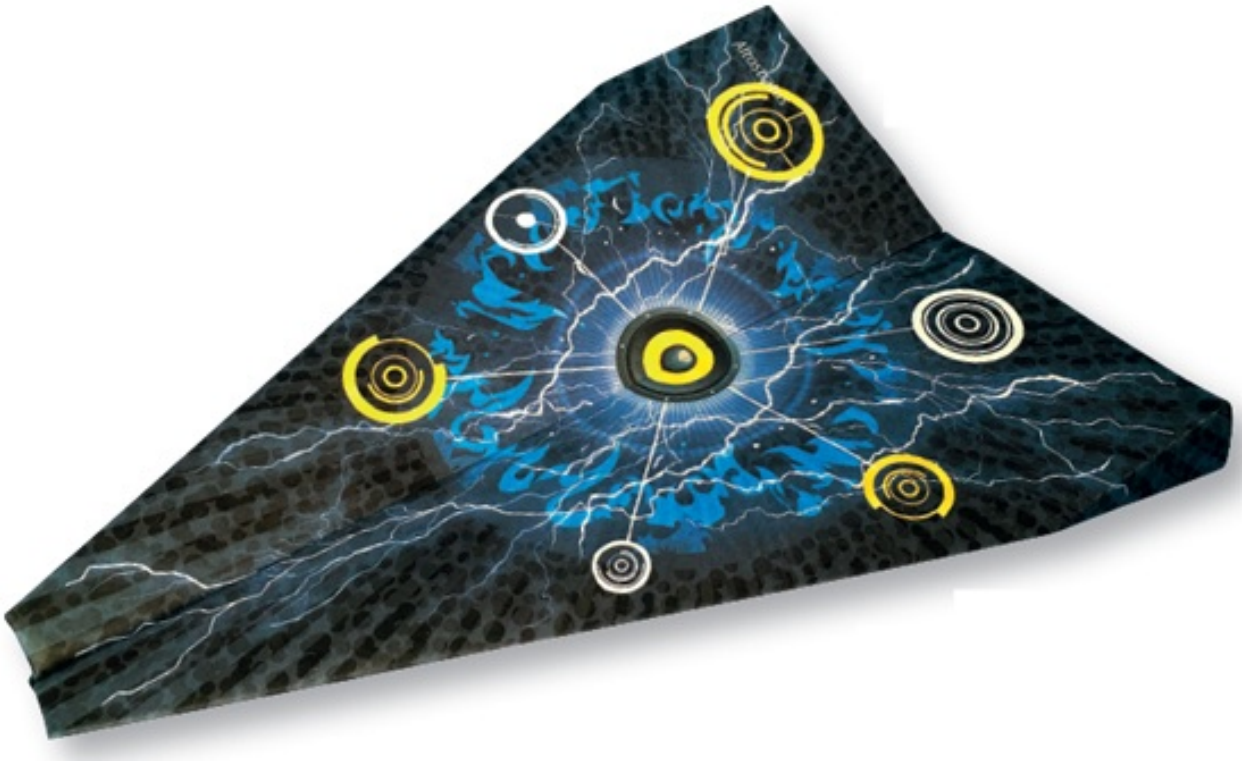


7 Fold down the wingtips on the 6 lines to make the rudders. The width is one and a half times the width of the fuselage.

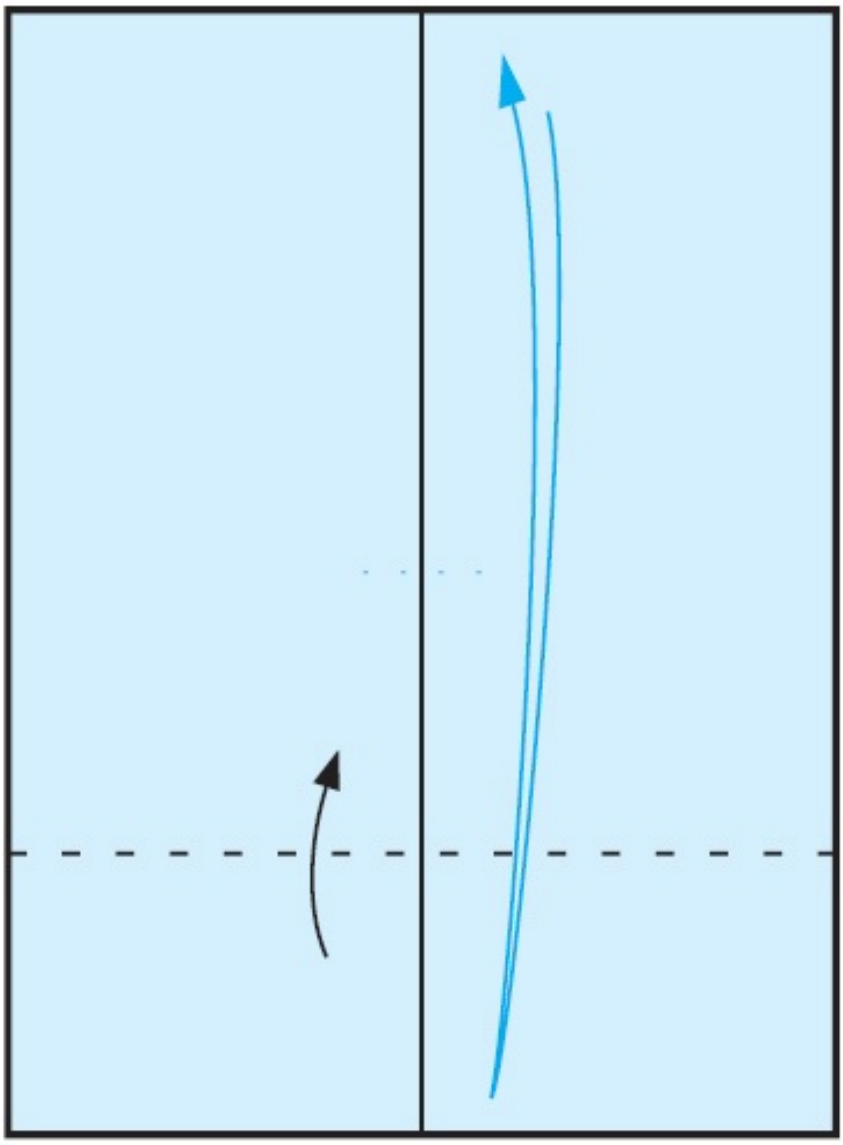
8 Straighten out the wings and rudders so that they look like this when seen from the front. Squash the folds as flat as you can, and you're done!

ALTOSTRATUS

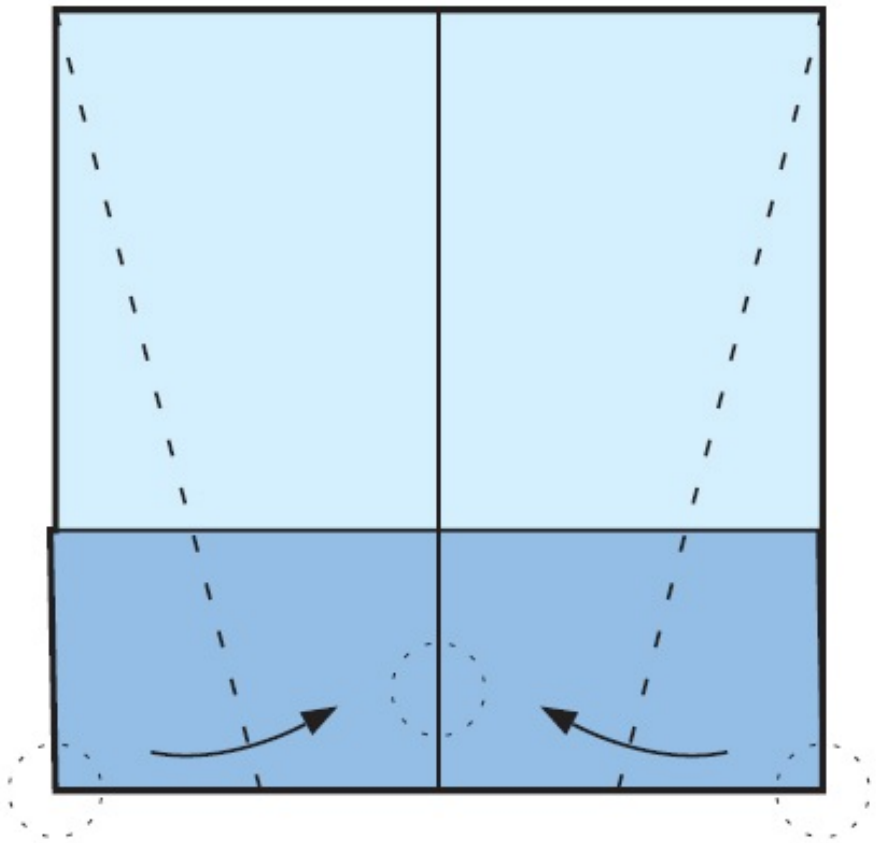
This plane starts out like the Arrow and the Stratus, but the nose lock keeps it tighter, and the double leading edge folds make the wing very stiff and strong, so you can throw it as hard and high as you like.



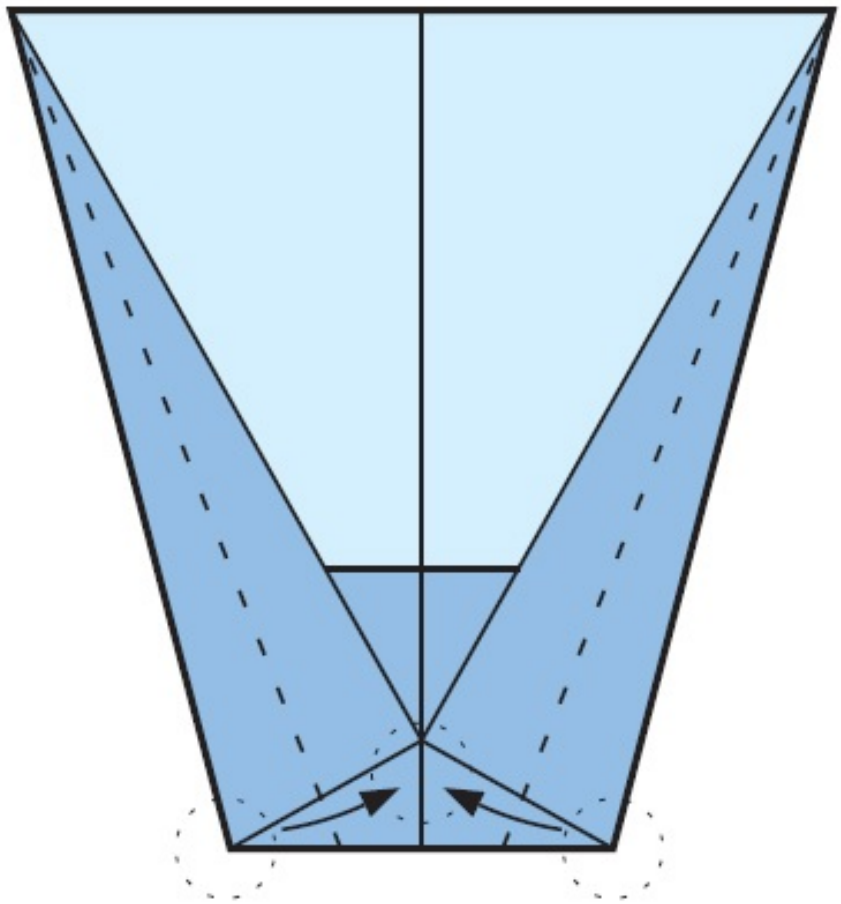
Author's Average
Distance Flown: 22 Yards
Author's Average
Time Aloft: 15 Seconds



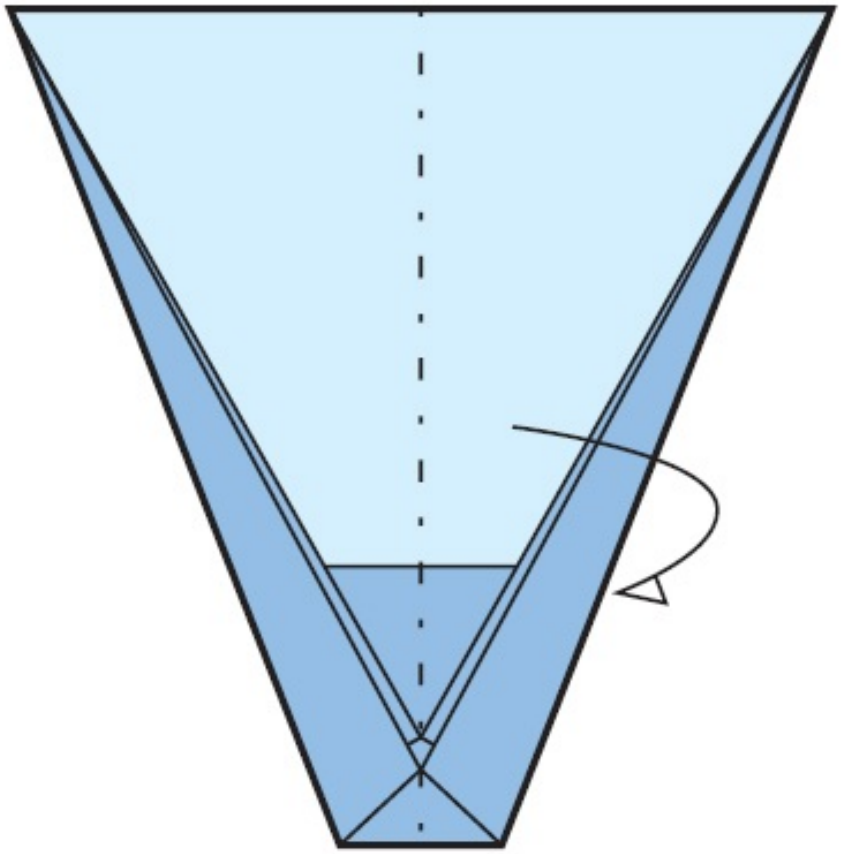
1 Start with the paper face down, and fold the bottom edge up to the middle on line 1.



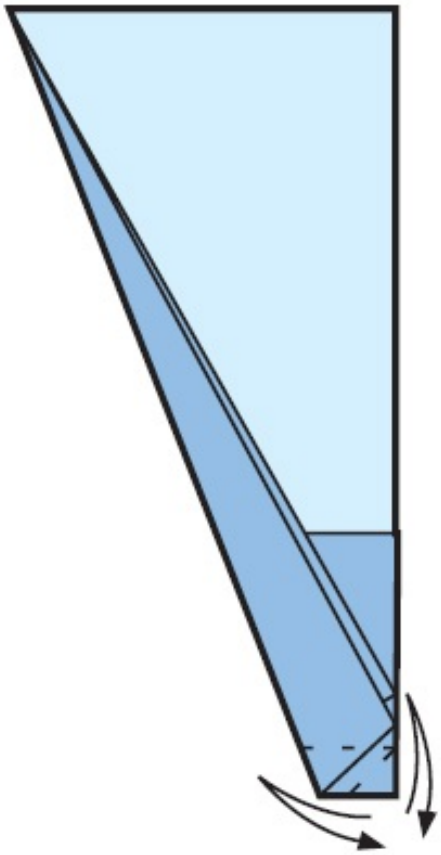
2 Fold the bottom corners in to the center line on the 2 lines as shown.



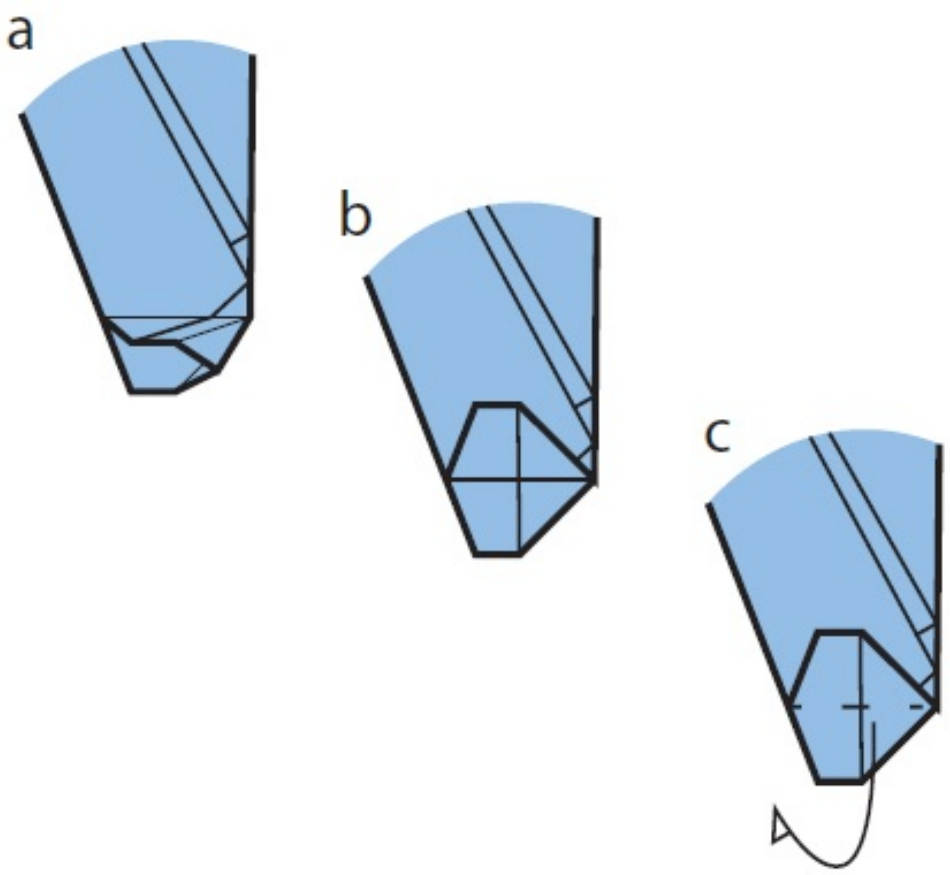
3 Fold the corners in again, the same way, on the 3 lines.



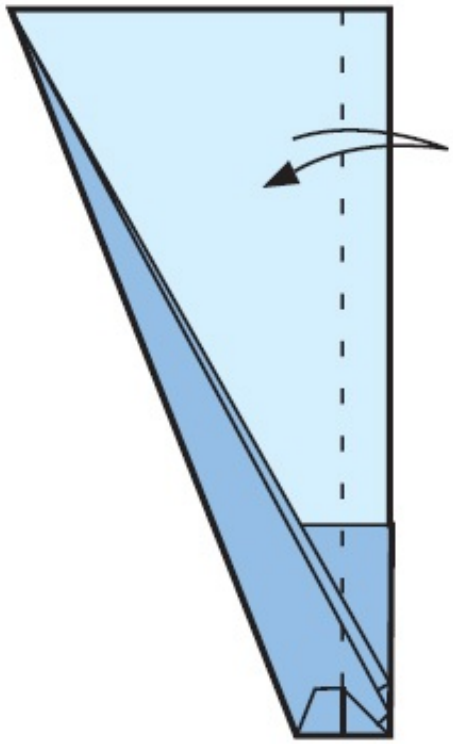
4 Fold the plane in half away from you.



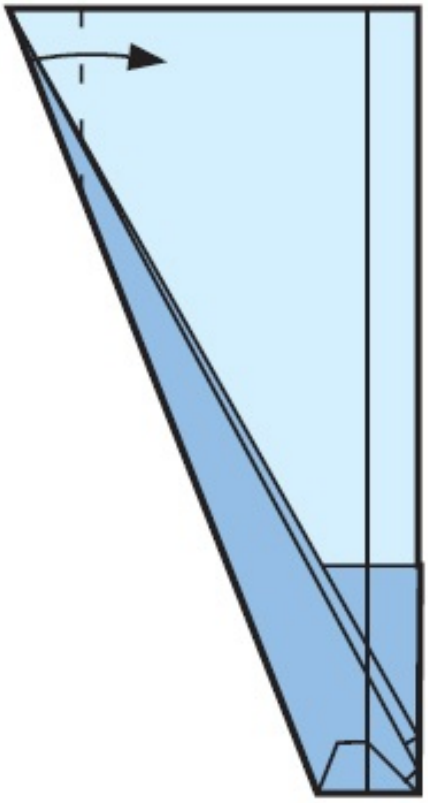
5 Fold and unfold on lines 4 and 5. The crease at 4 starts where the paper gets thick under the folded edges.



6 Pull the top layer of the nose up and fold it right back over. The bottom right corner will flip up and flatten on the 5 lines. Fold the lower layer to the other side.



7 Fold and unfold the wings on the 6 lines. The fold starts at the loose edge in the nose and runs parallel to the center line.

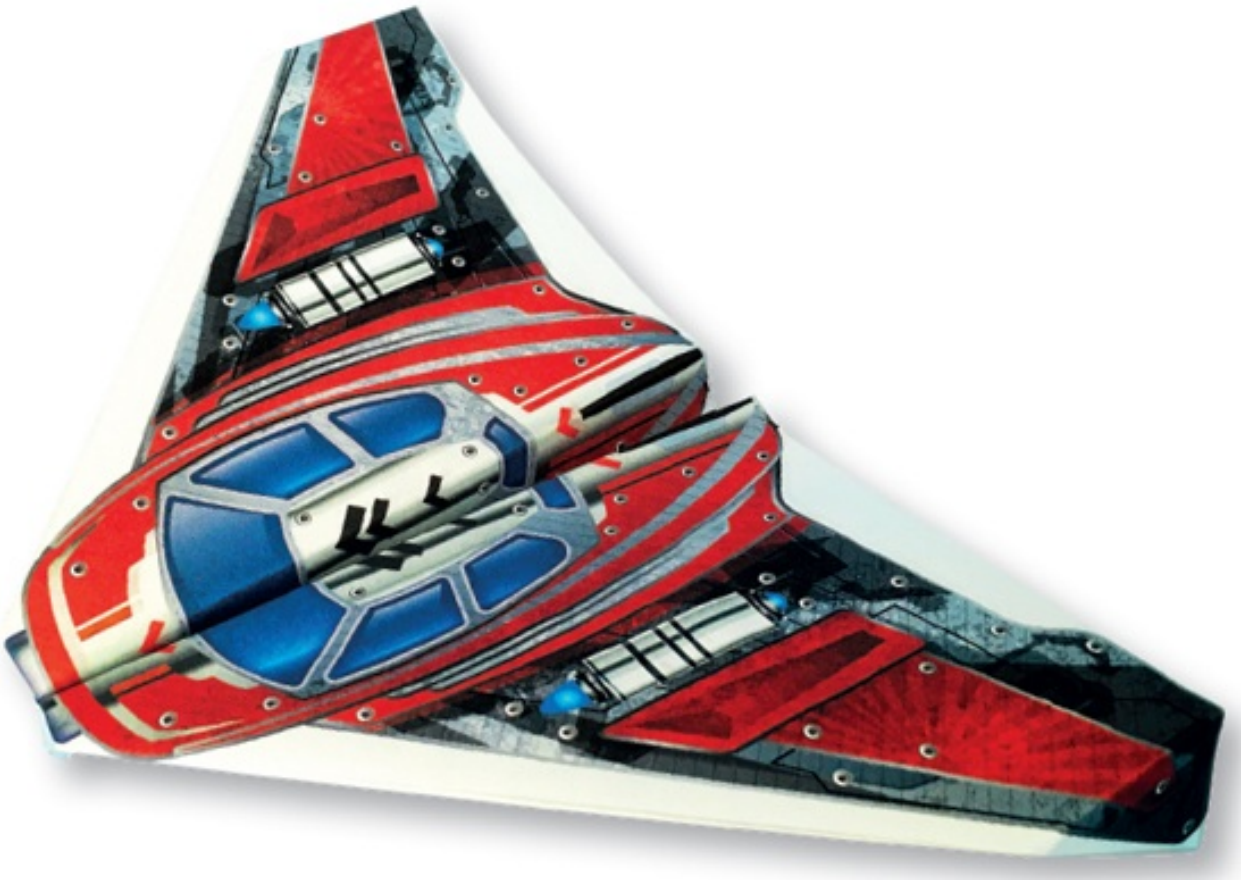


8 Fold the wingtips on the 7 lines to make the rudders.

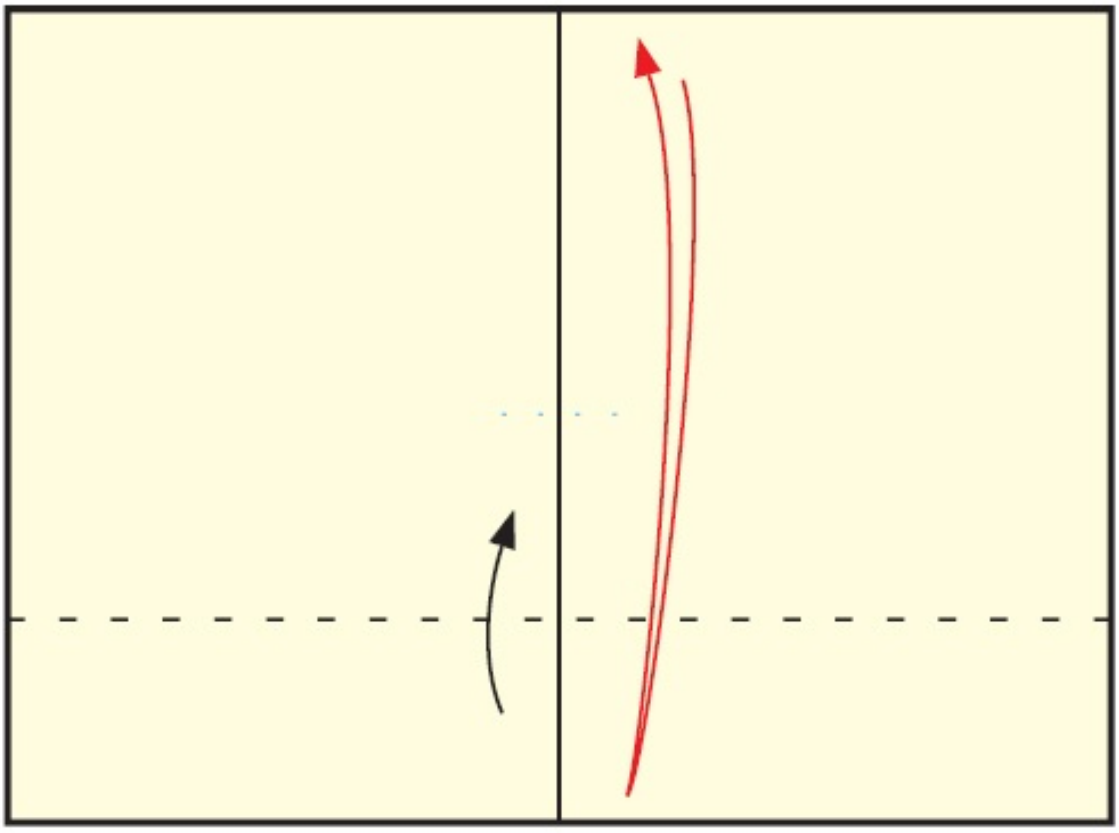
9 Straighten out the wings and rudders so that they look like this when seen from the front. Squash the folds as flat as you can, and you're done!

STRATO TAXI

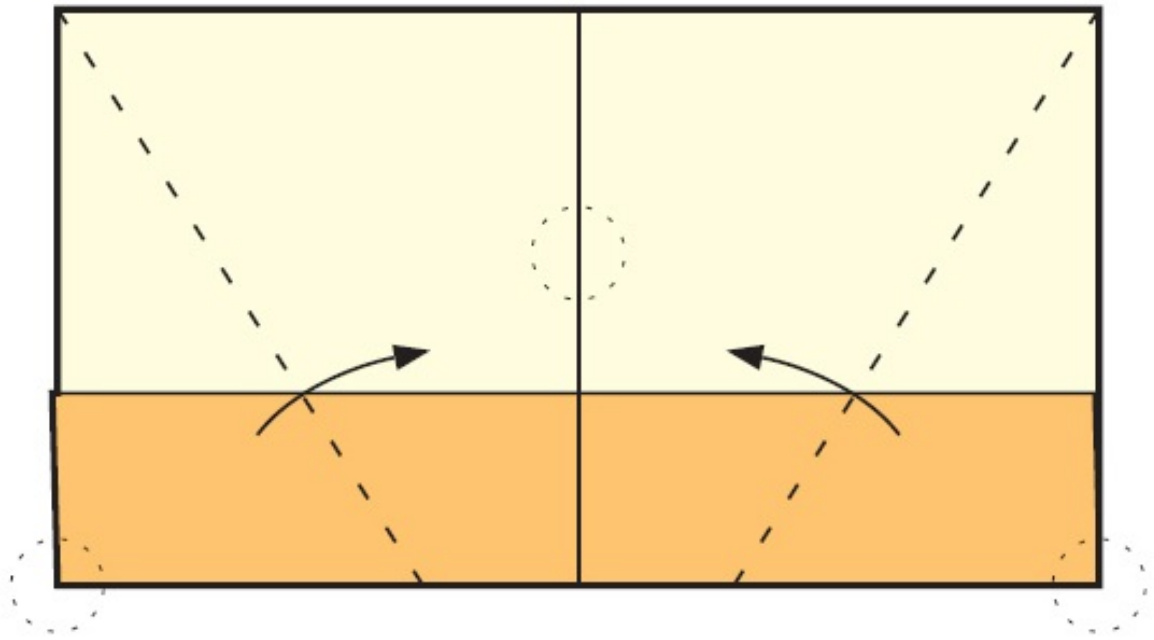
By putting the center line along the width of the paper instead of the length, it is possible to have wider, narrower wings. Long, narrow wings are more efficient at slow speeds, so this plane has a very flat glide.



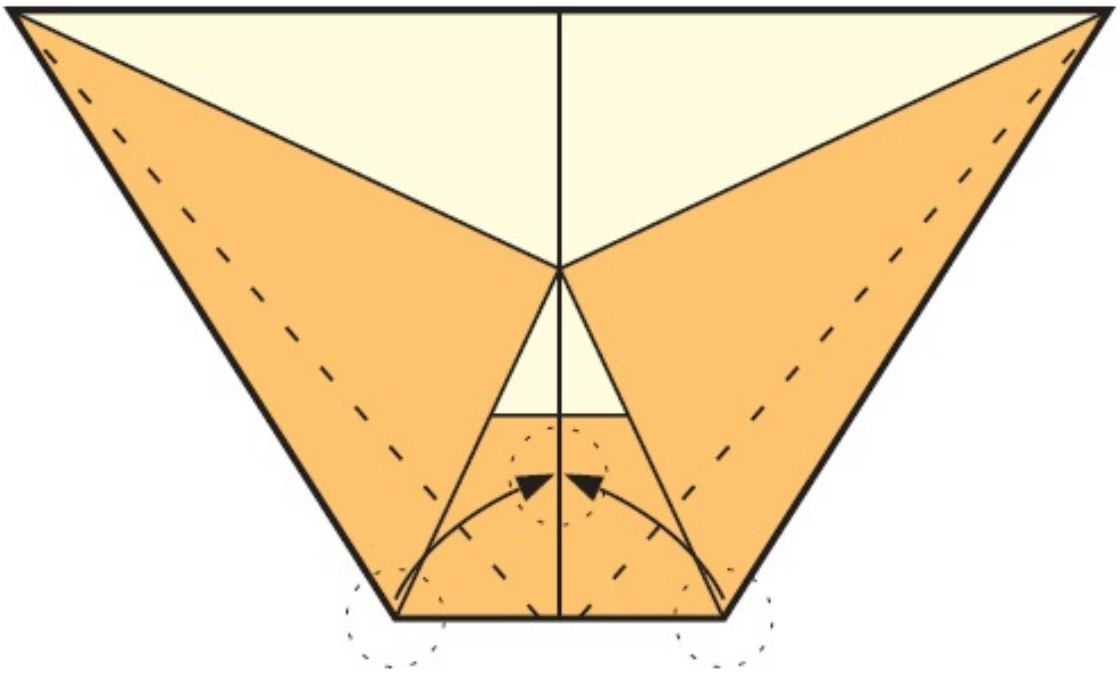
Author's Average
Time Aloft: 22 Seconds



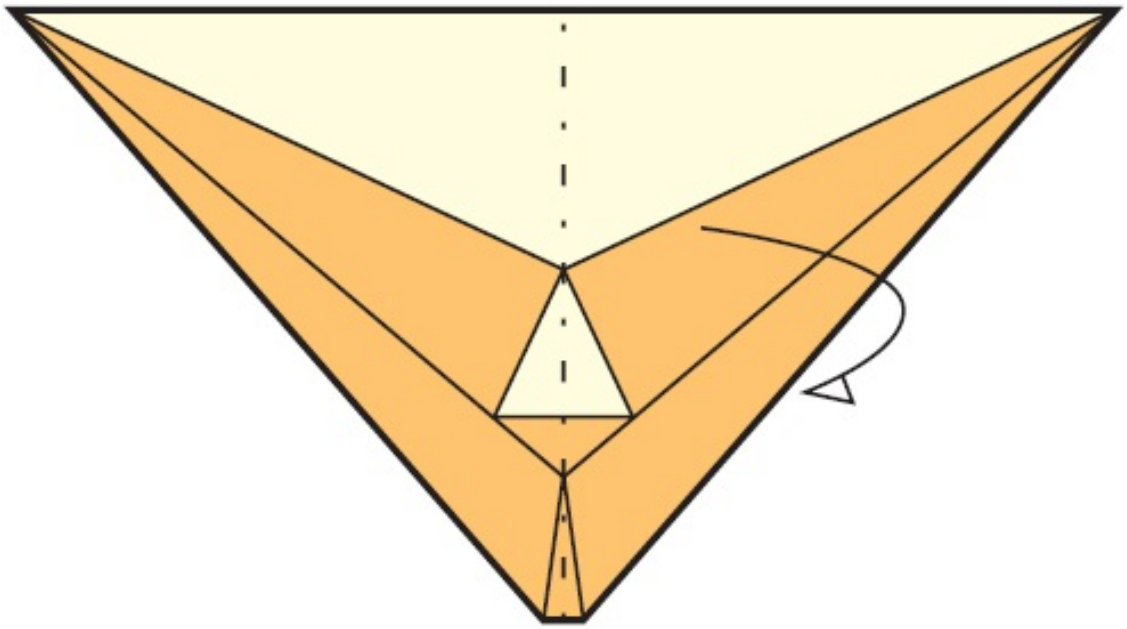
1 Start with the paper face down. Fold up the bottom edge on line 1 to the center of the paper.



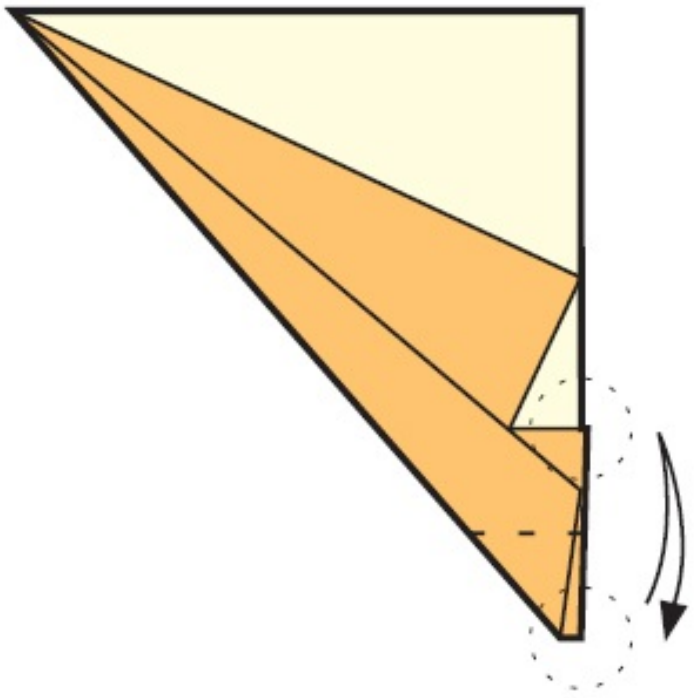
2 Fold the bottom corners up on the 2 lines until they just meet at the center line.



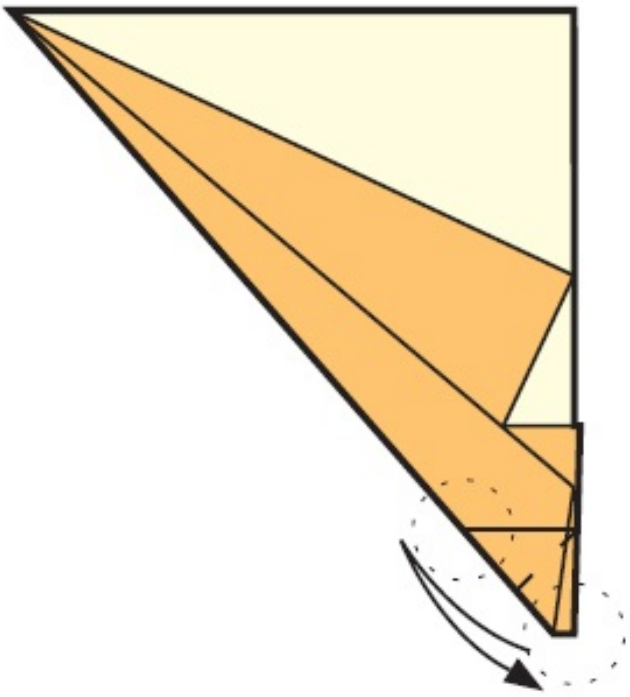
3 Fold the new corners in the same way on the 3 lines.



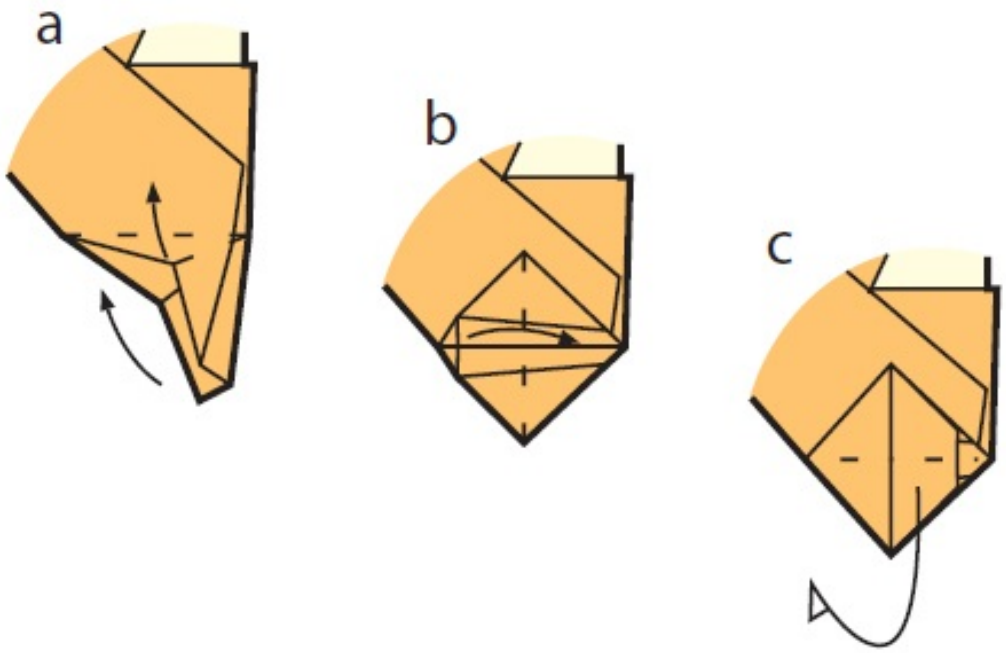
4 Fold the plane in half away from you.



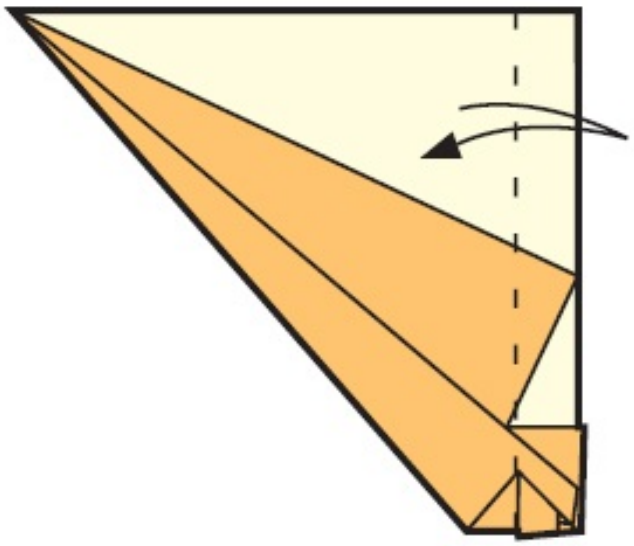
5 Fold and unfold the nose on line 4, halfway between the two corners shown.



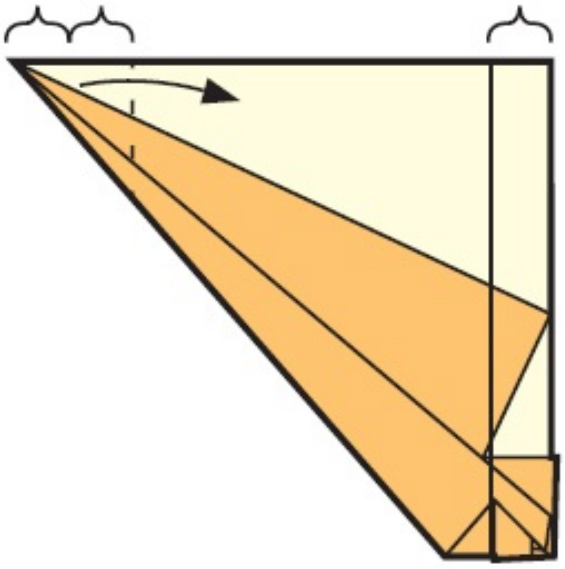
6 Fold and unfold on line 5.



7 Fold and unfold the wings on the 7 lines, starting at the center of the nose.



8 Pull the top layer of the nose up and fold it right back over. The bottom right corner will flip up and flatten on the 5 lines. Fold the tip down on line 6, and then fold the lower layer to the other side.



9 Fold the wingtips down on the 8 lines to make the rudders. They are twice the width of the fuselage.

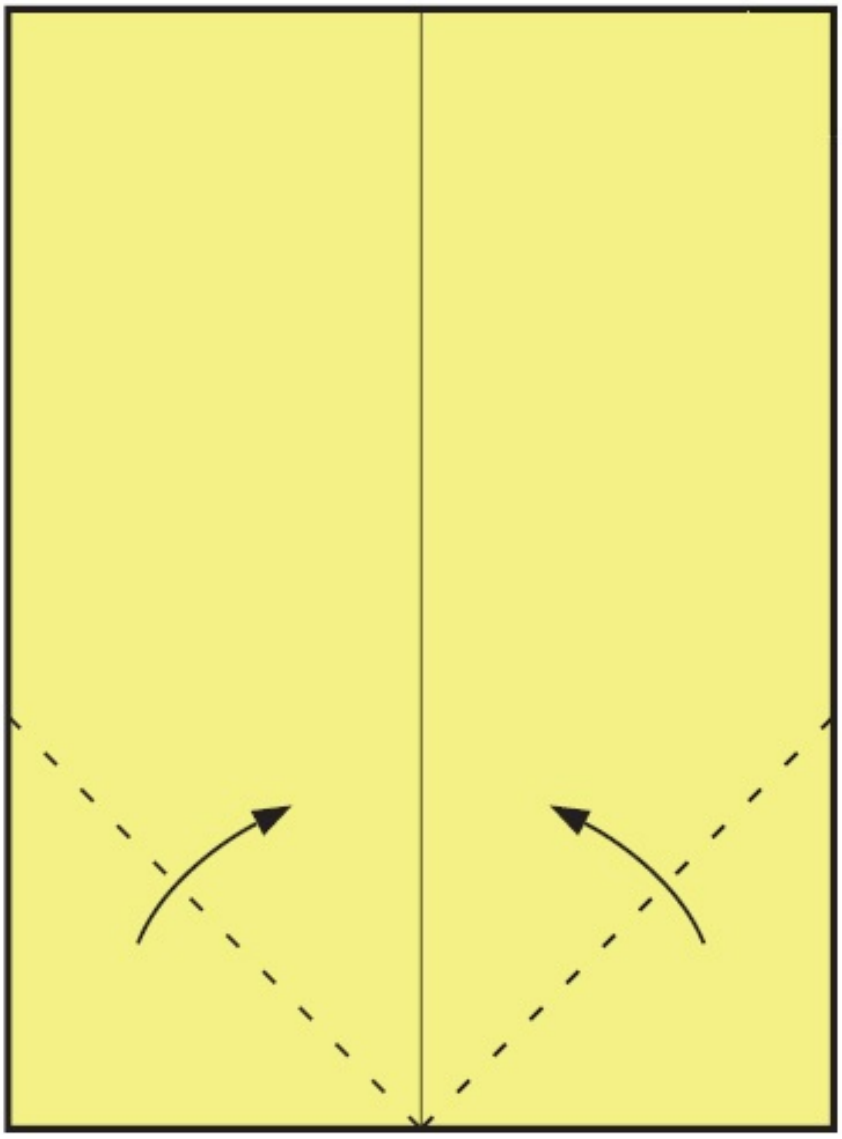
10 Open out the wings and rudders so that they look like this when seen from the front. Squash the folds on the front edge of the wing as flat as you can.

Airframe Note: This is probably the most robust plane in the kit, after the Sprint.

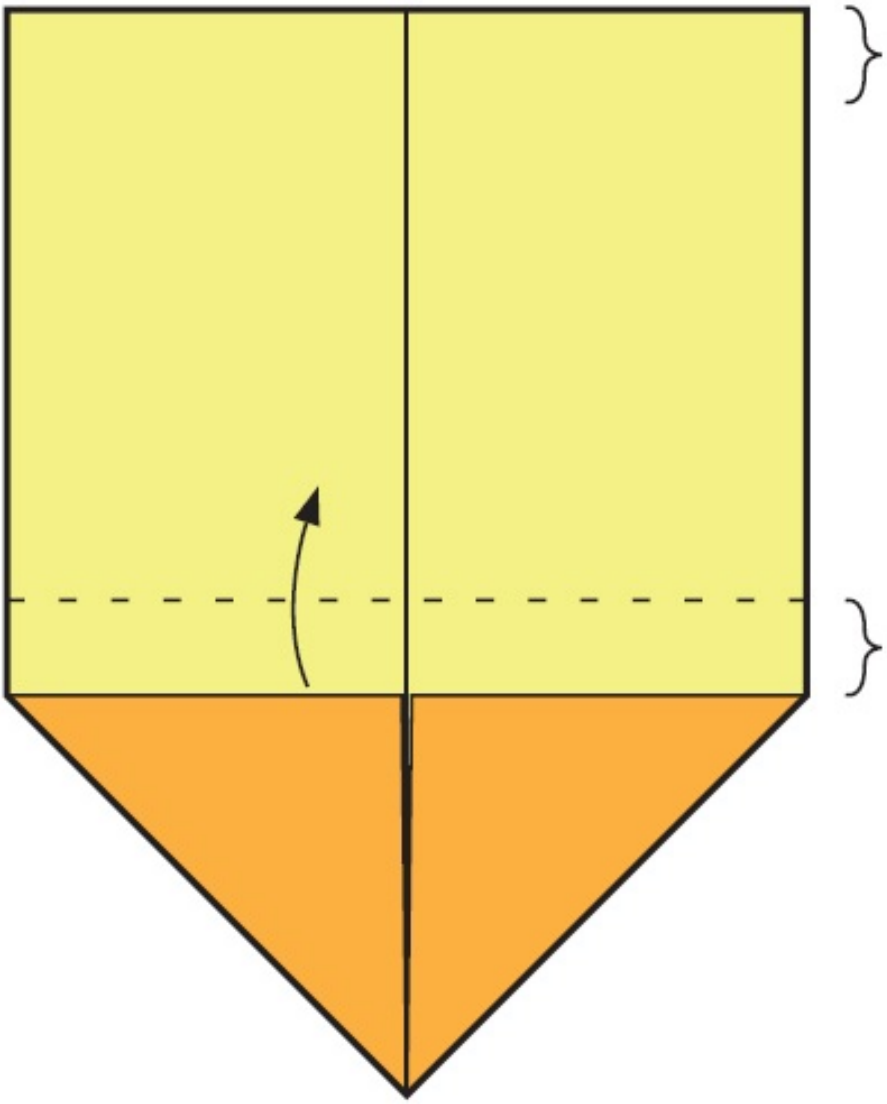
STORMCLOUD

This plane starts out as a belly button airplane, the most common Japanese paper airplane, but then turns into a broad-winged Toda-style airplane. Belly button planes waft, but this one soars!

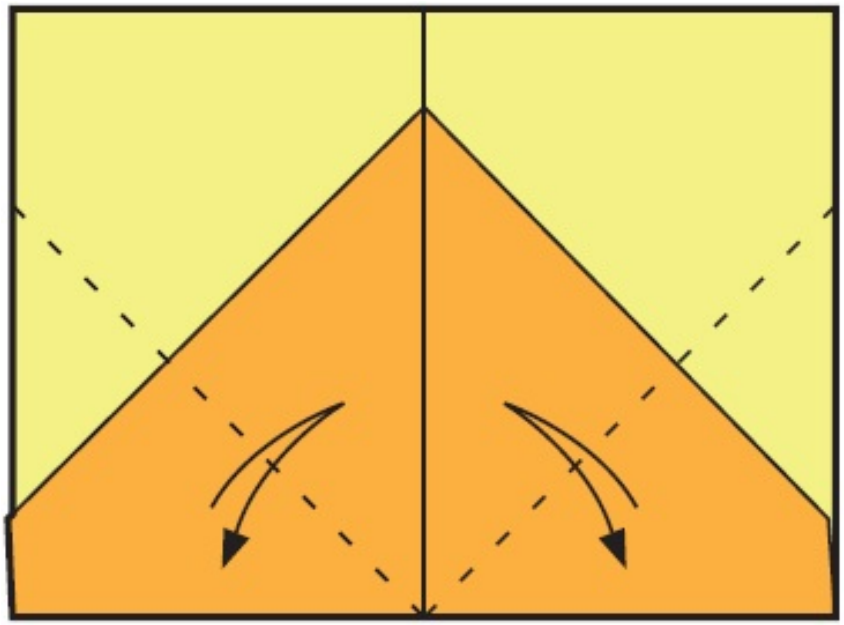
Author's Average
Time Aloft: 17 Seconds



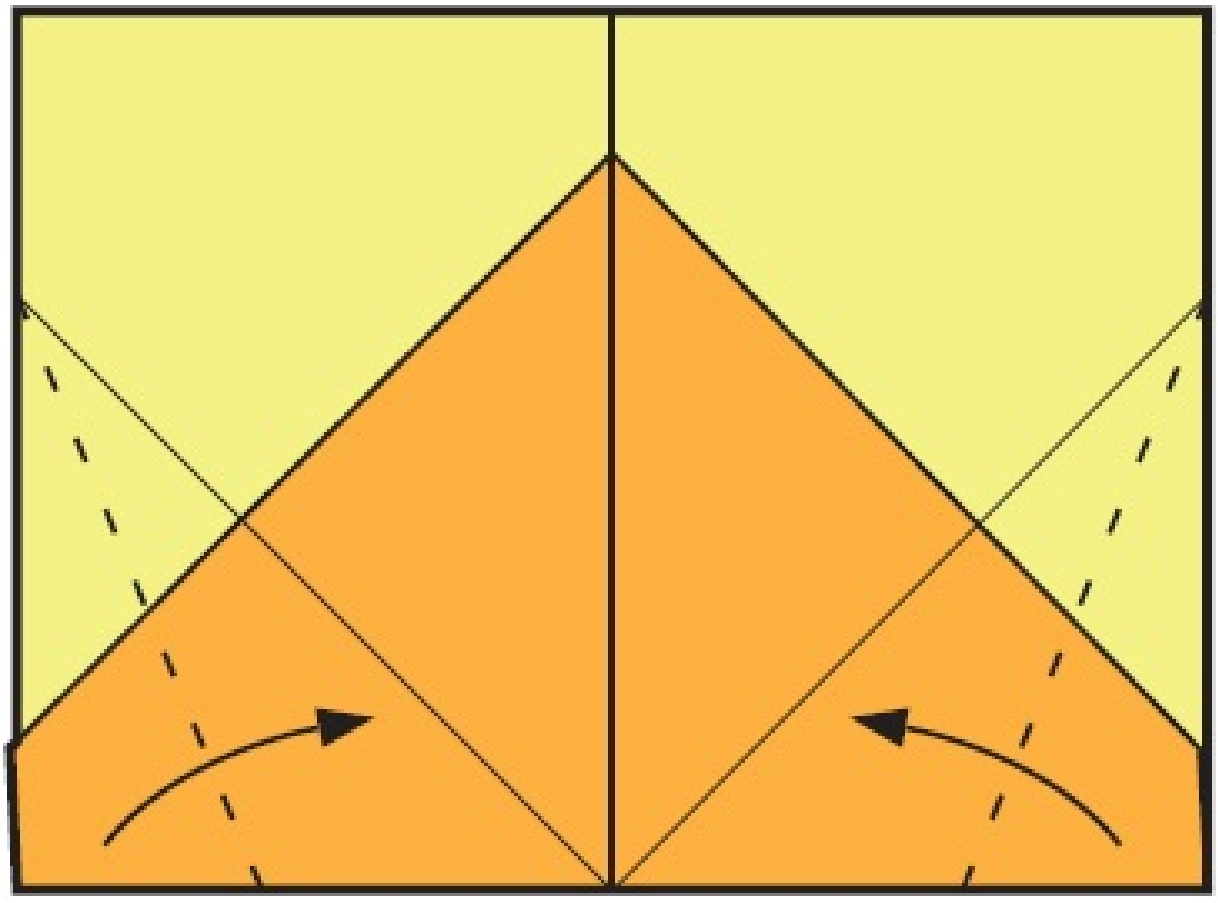
1 Start with the paper face down. Fold the two bottom corners in to the center on the 1 lines.



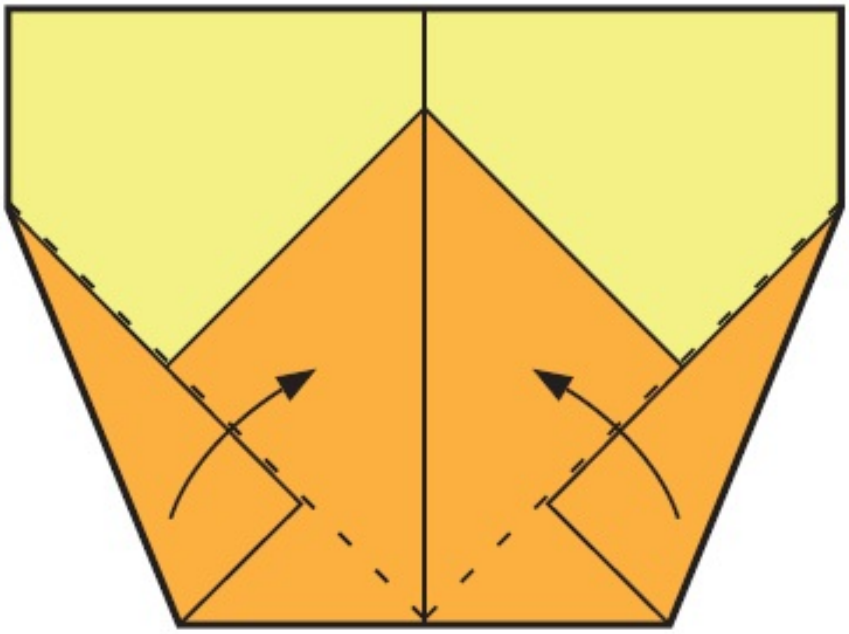
2 Fold the bottom part of the paper up on line 2. The next step shows how the extra width at the top and bottom will be about the same.



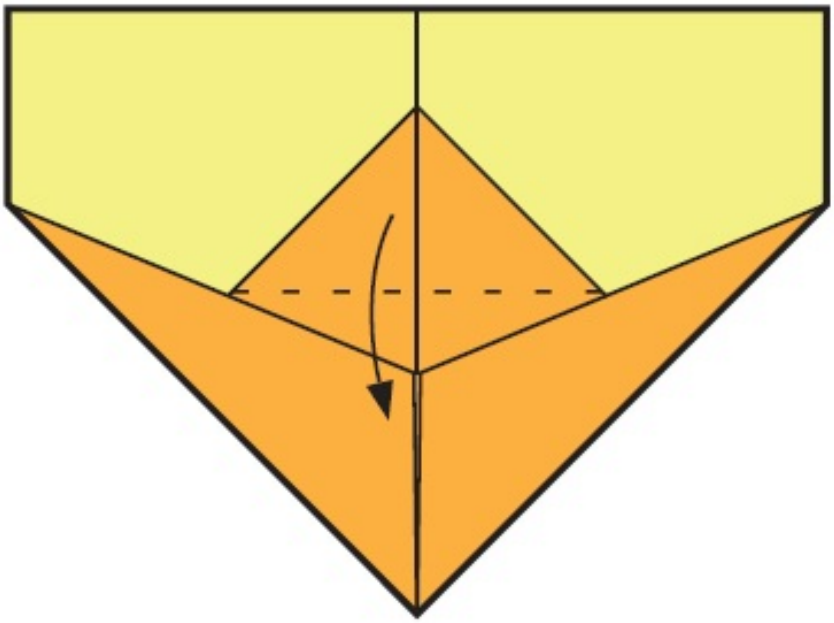
3 Fold and unfold the new bottom corners on the 3 lines.



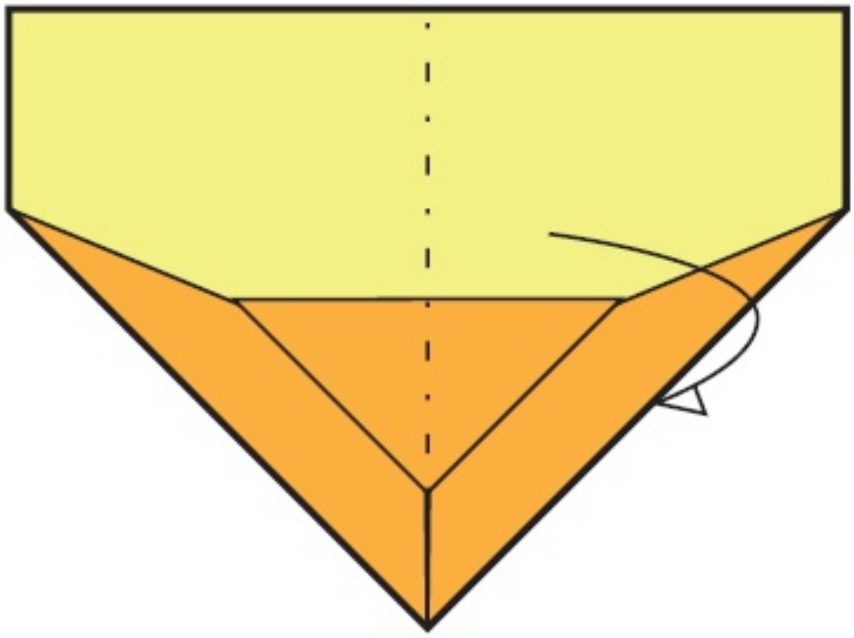
4 Fold the corners on the 4 lines, so the edges touch the creases you made in the last step.



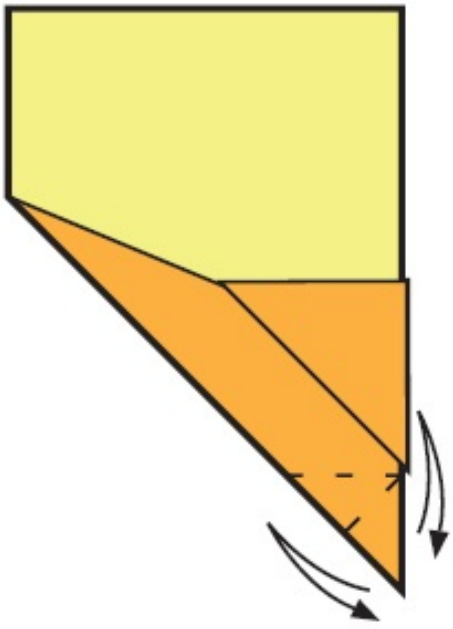
5 Refold on the 3 lines.



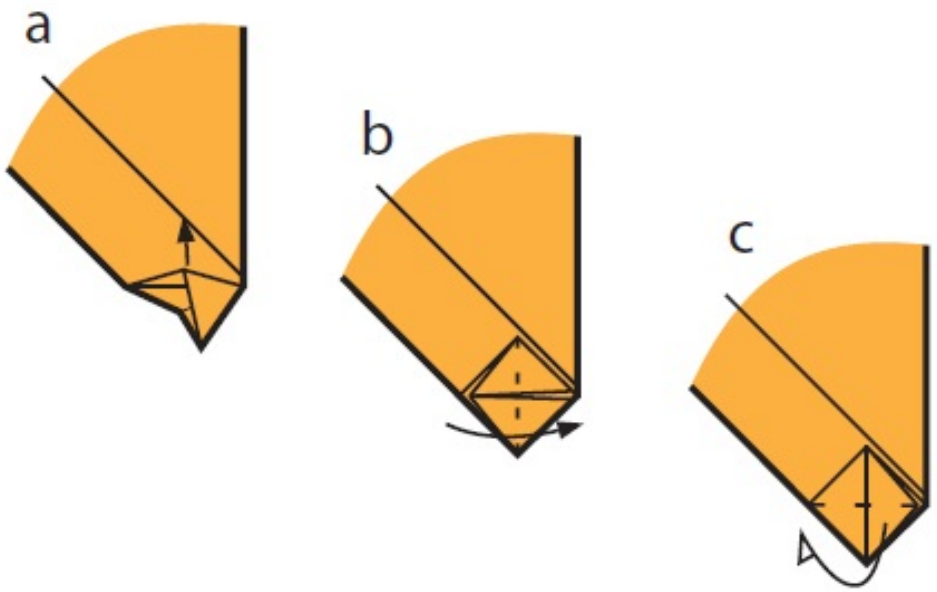
6 Fold the loose triangle down on line 5. This is the “belly button.”



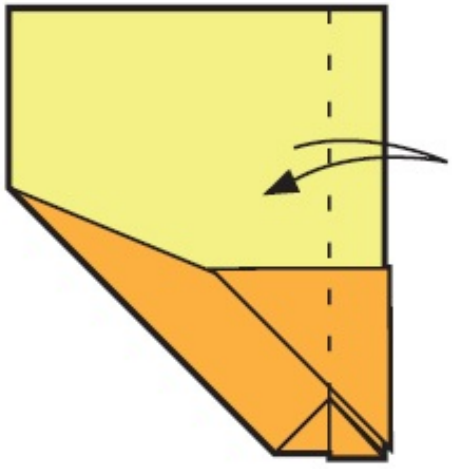
7 Fold the plane in half away from you.



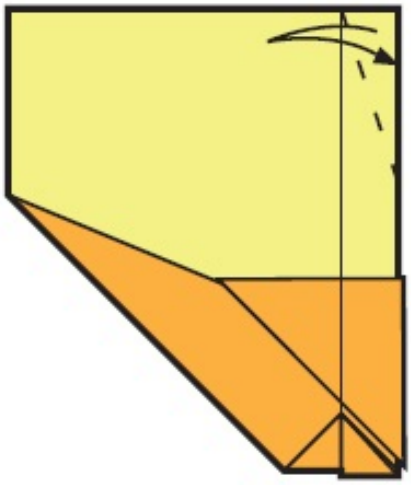
8 Fold and unfold on lines 6 and 7. Line 6 starts where the paper gets thick.



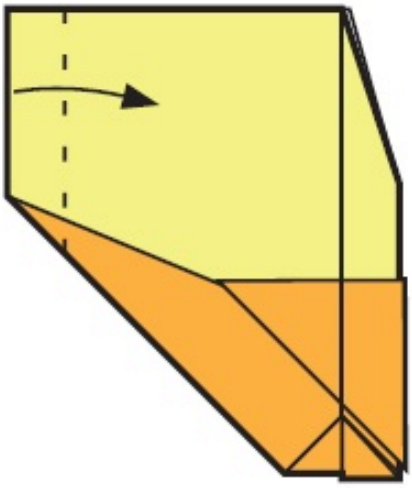
9 Pull the top layer of the nose up and fold it right back over. The bottom right corner will flip up and flatten on the 7 lines. Fold the tip down on line 8, and then fold the lower layer to the other side.



10 Fold and unfold the wings on the 9 lines.



11 Fold, unfold, and reverse fold the rudder on line 10.

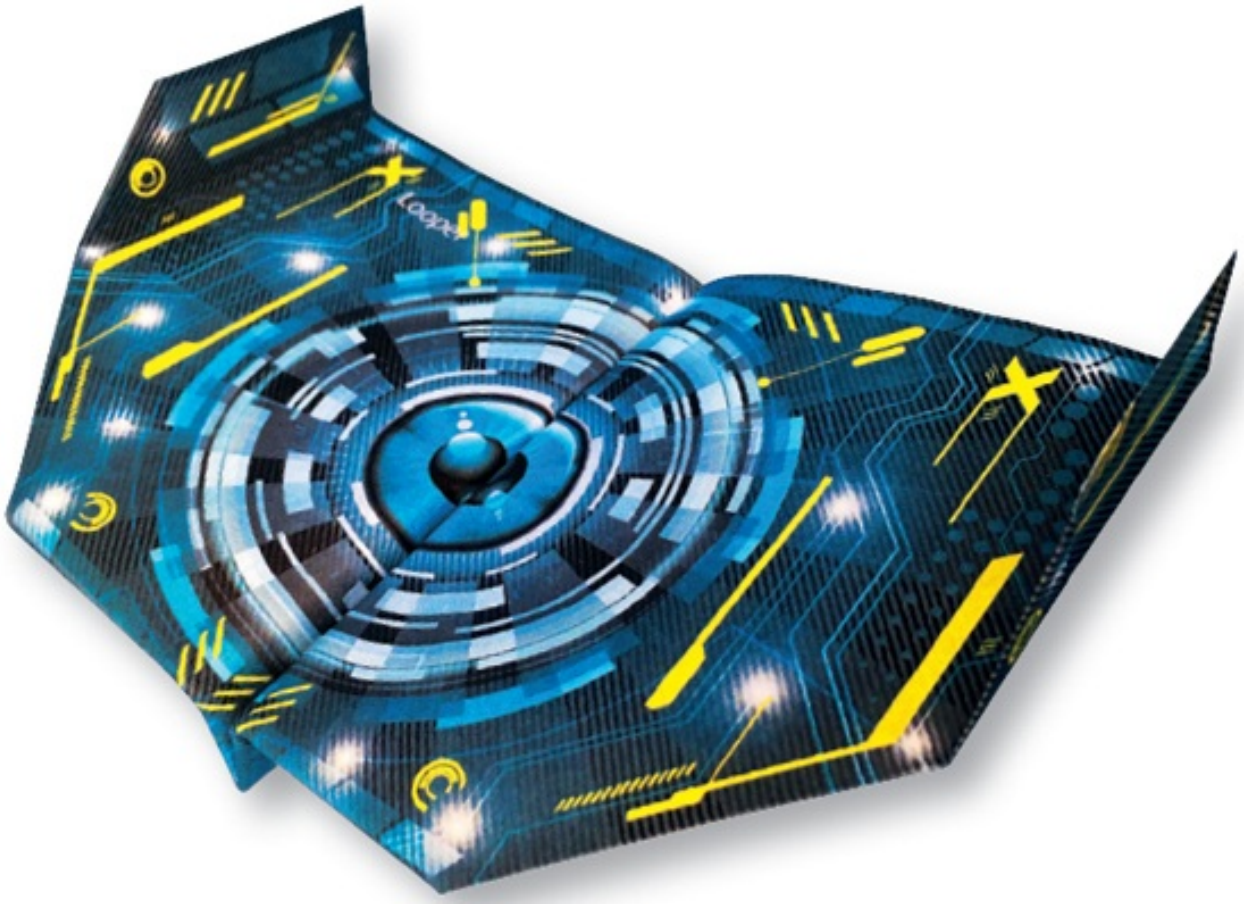


12 Fold down the wingtips on the 11 lines.

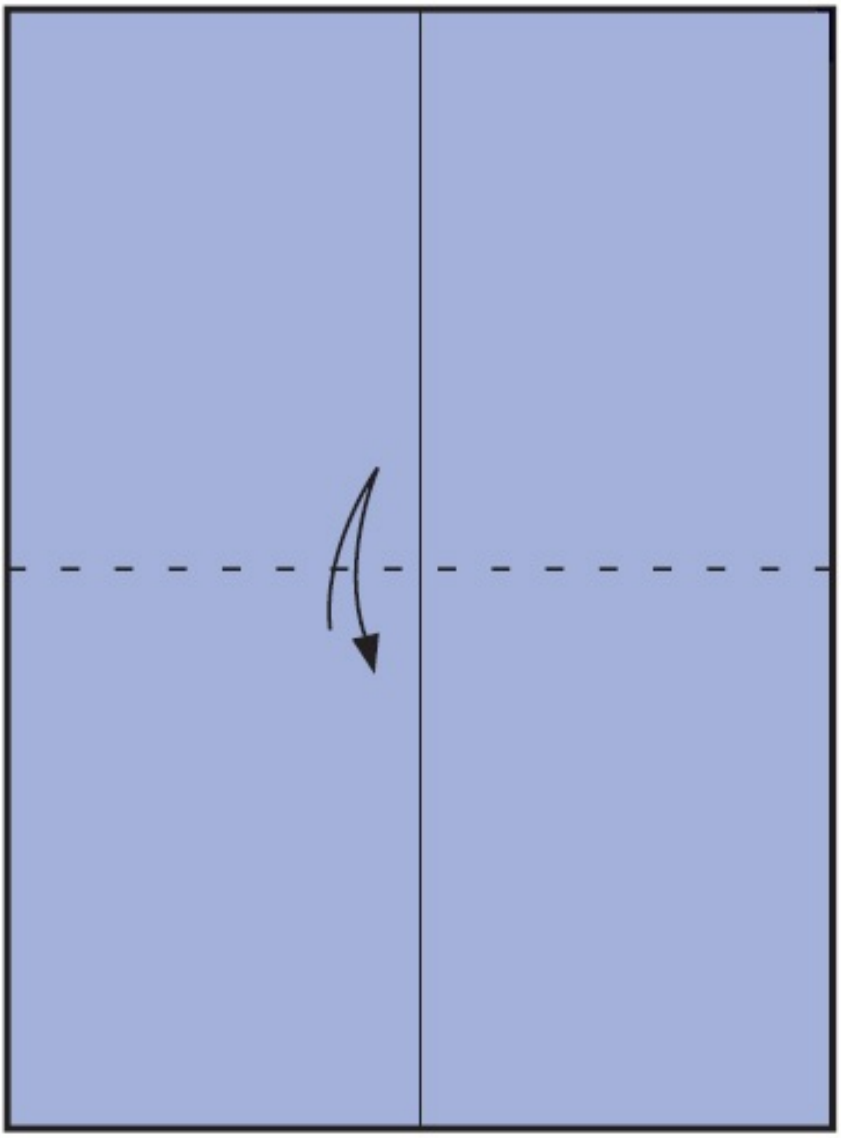
13 Spread the wings and rudder so that they look like this from the front.

THE LOOPER

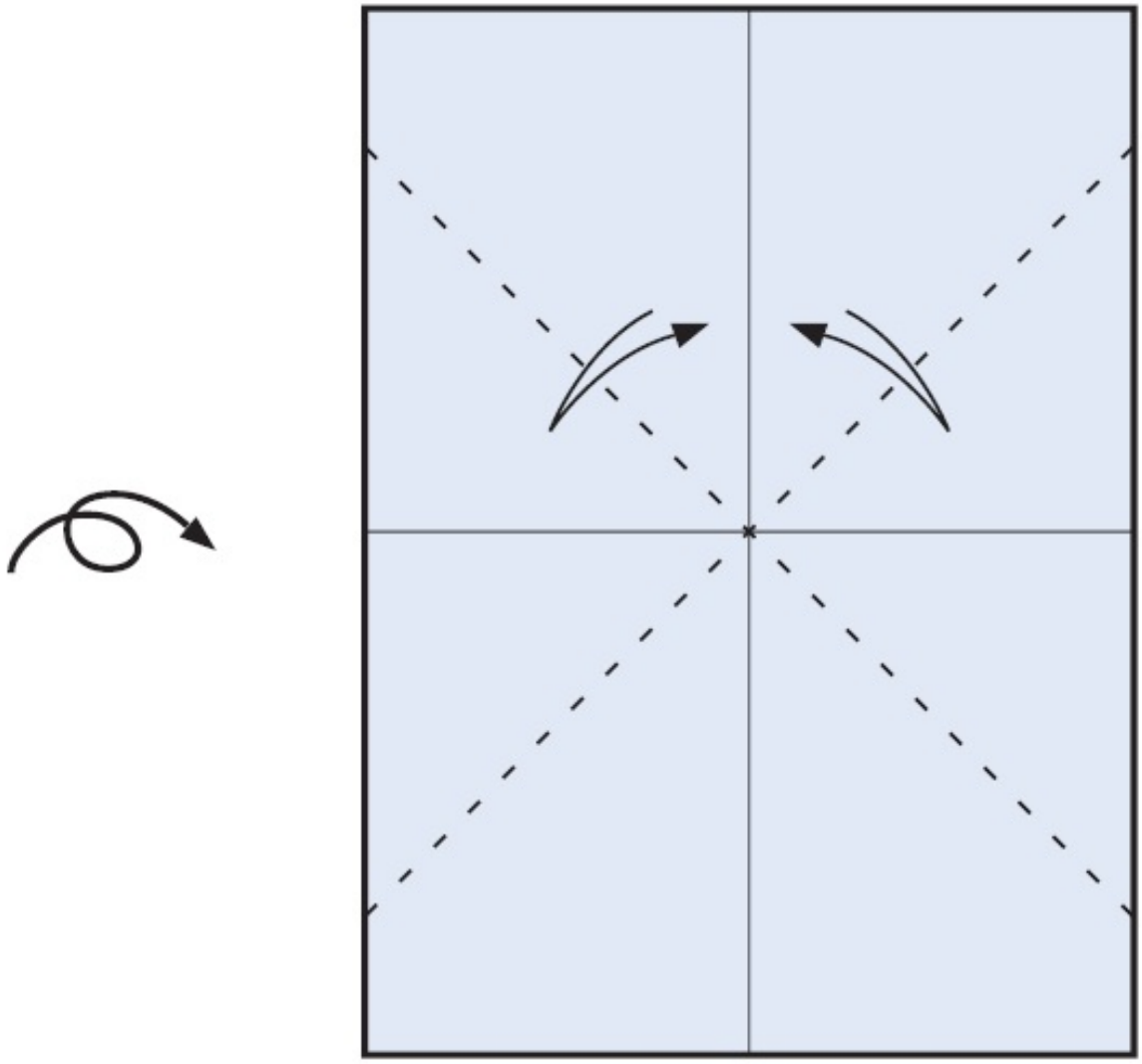
The very first international paper airplane contest had a category for acrobatics, so I've added an acrobatic plane you can experiment with. Throw it hard and it will loop or come back to you. There's no world record for acrobatics yet. Care to try to set one?



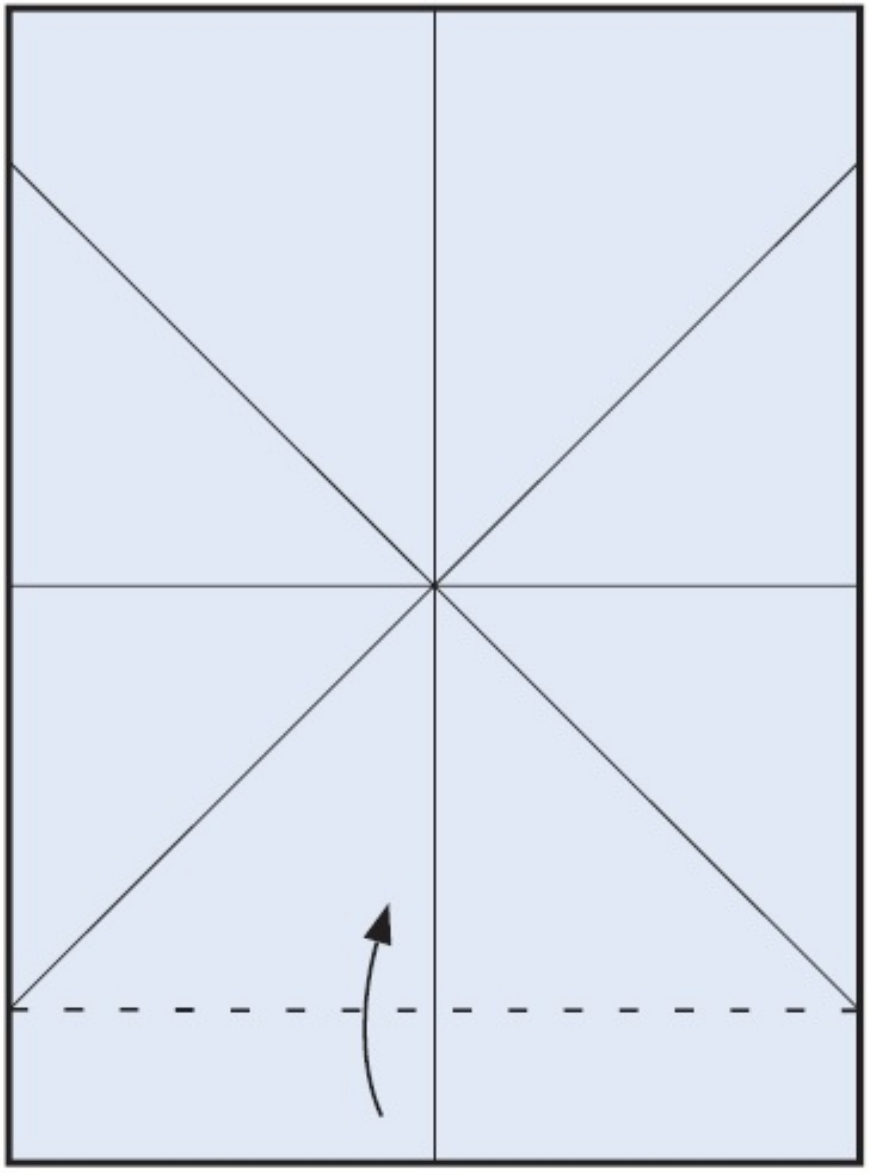
Author's Average
Time Aloft: 12 Seconds



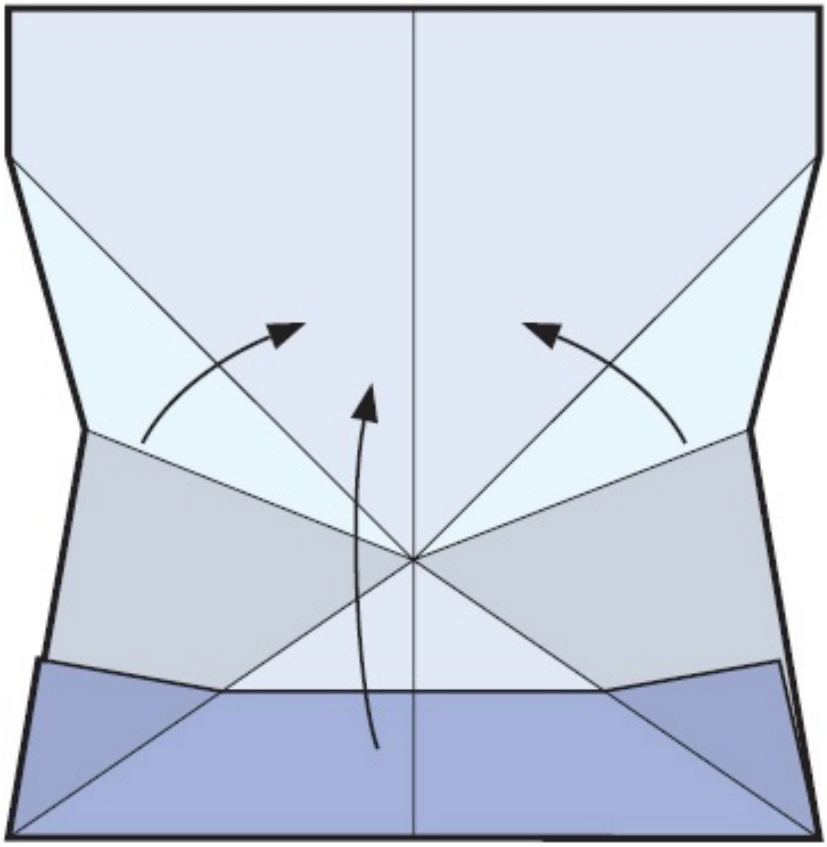
1 Start with the paper face side up. Fold it in half and unfold. Flip the paper over.



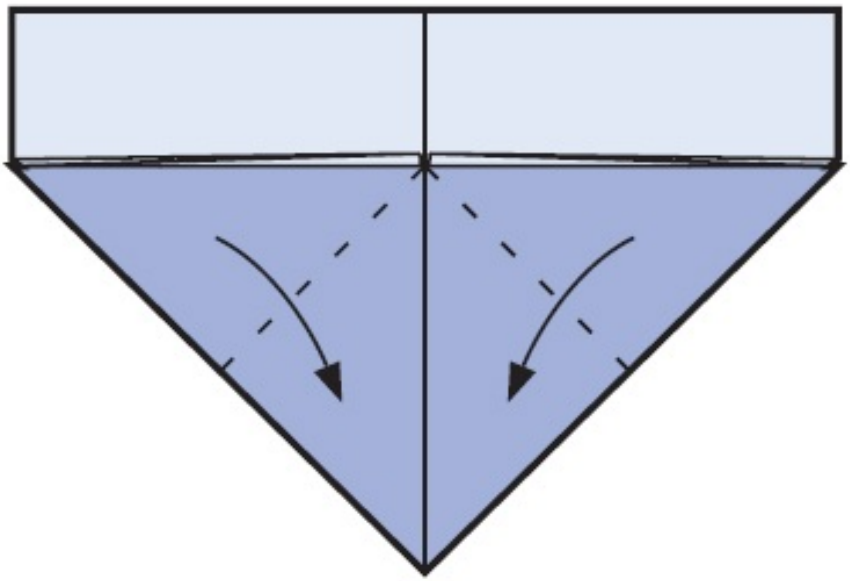
2 Fold and unfold on lines 2 and 3.



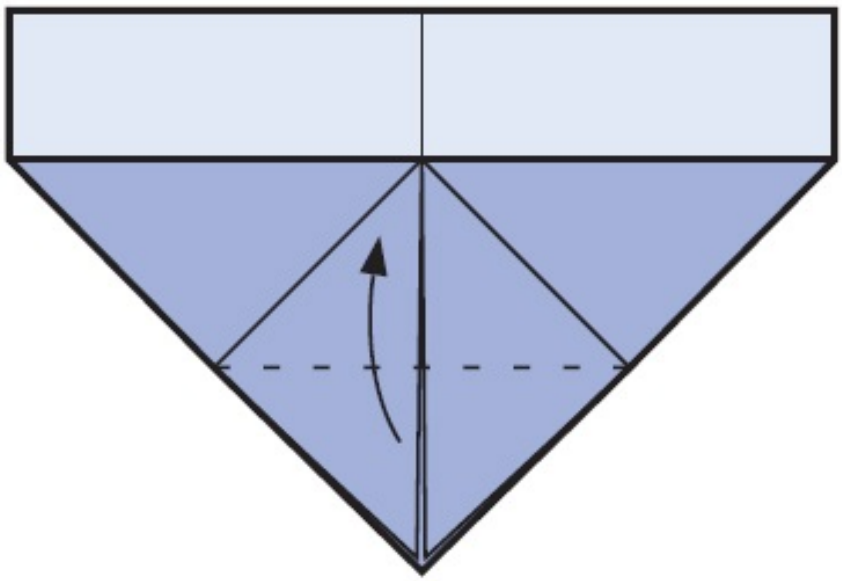
3 Fold up the bottom edge of the paper on line 4, as shown.



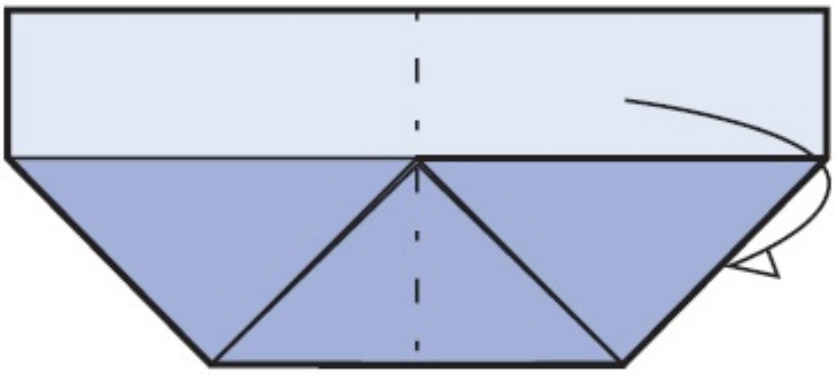
4 Pull the two sides of the paper upward and inward, recreasing the bottom flap as you go. Step 5 shows how the fold will end up.



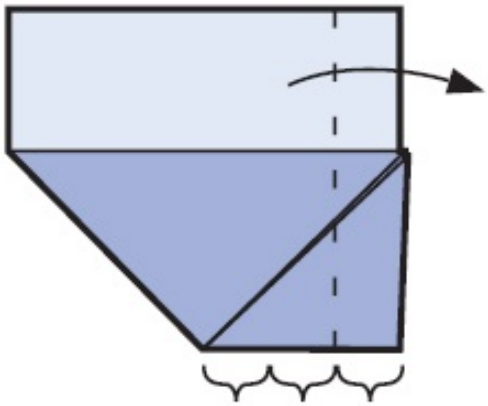
5 Fold the two loose corners down on the 5 lines to meet the tip of the nose.



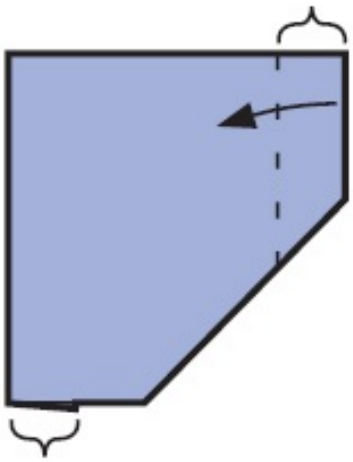
6 Fold the whole nose up on line 6.



7 Fold the plane in half away from you.



8 Fold the wings down on the 7 lines. The fold starts one third of the way across the bottom edge.



9 Fold the wingtips down on the 8 lines to make rudders. They are the same width as the fuselage.

10 Straighten the wings and rudders so they look like this from the front, and you're

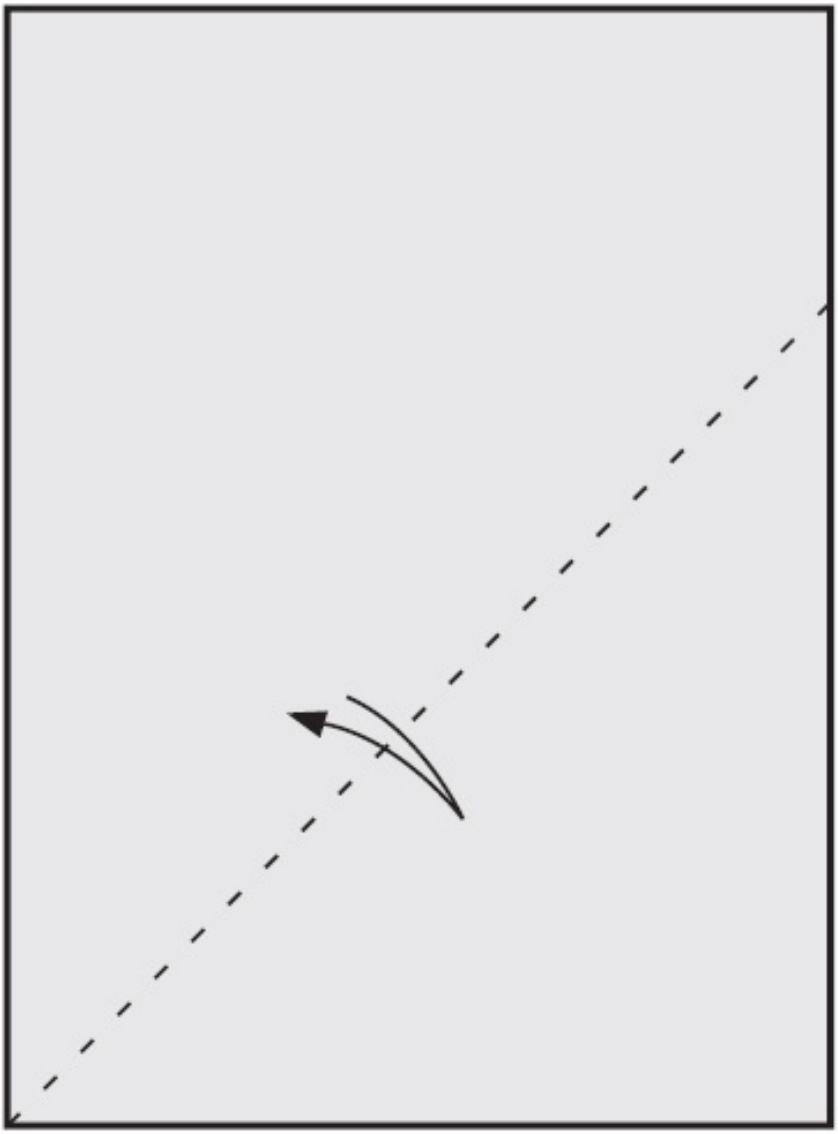
ready for acrobatic excitement!

Airframe Note: This plane is designed more for acrobatics than long flights, but is capable of good glides.

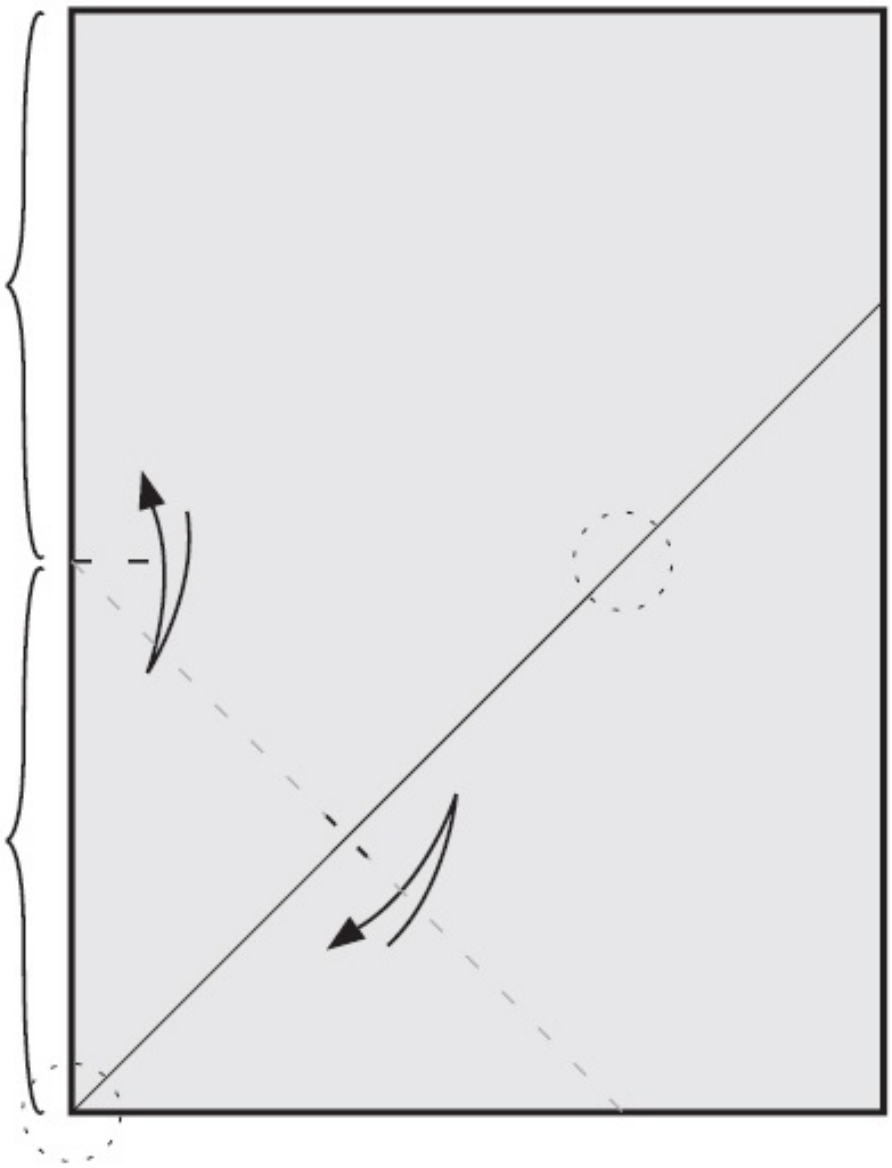
AEROSPIKE

The name of this plane comes from a kind of experimental rocket engine that will one day be used by space planes that can fly from a runway straight into orbit. Aerospike isn't exactly hypersonic, but it's close!

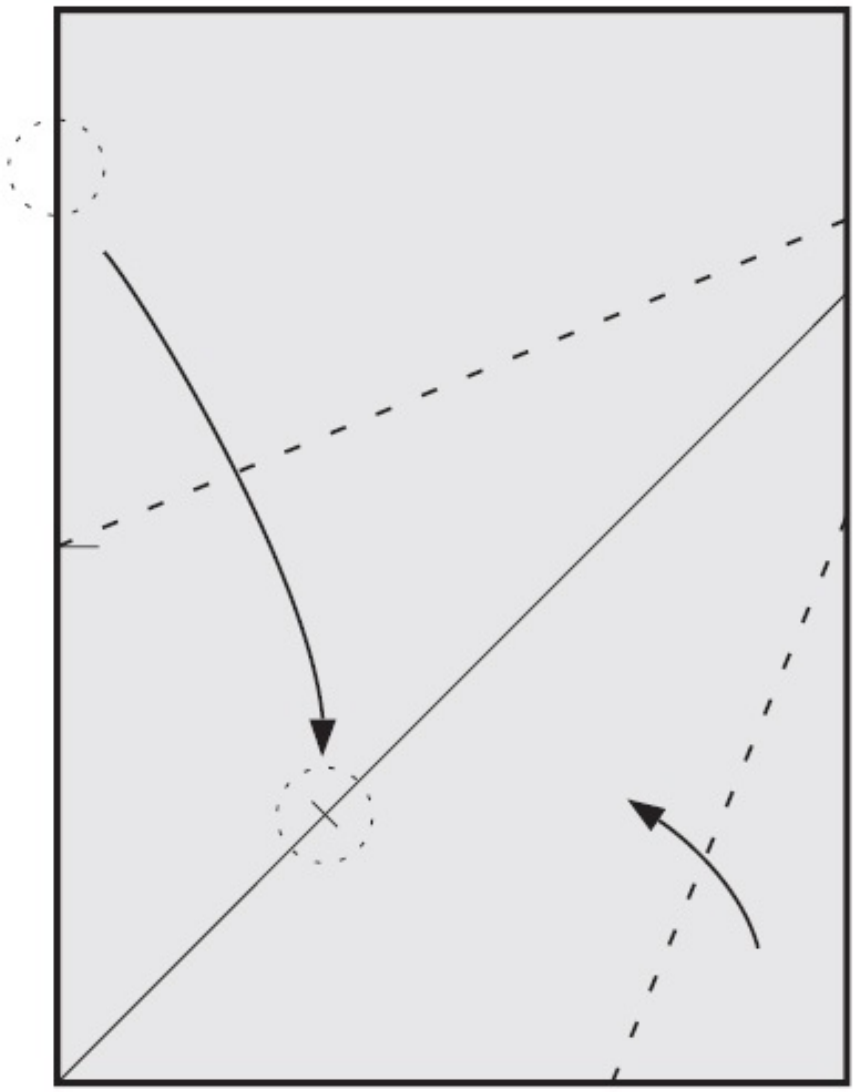
Author's Average Distance Flown: 31 Yards



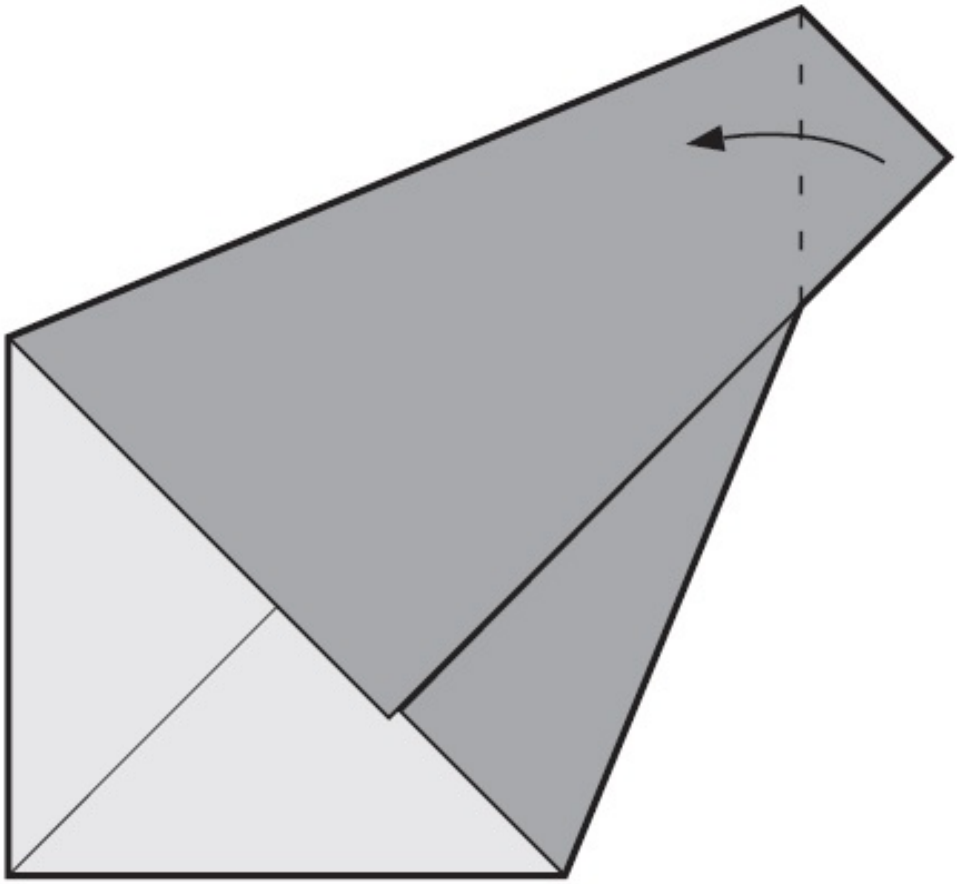
1 Start with the paper face down. Fold and unfold line 1, so the bottom edge just meets the left edge.



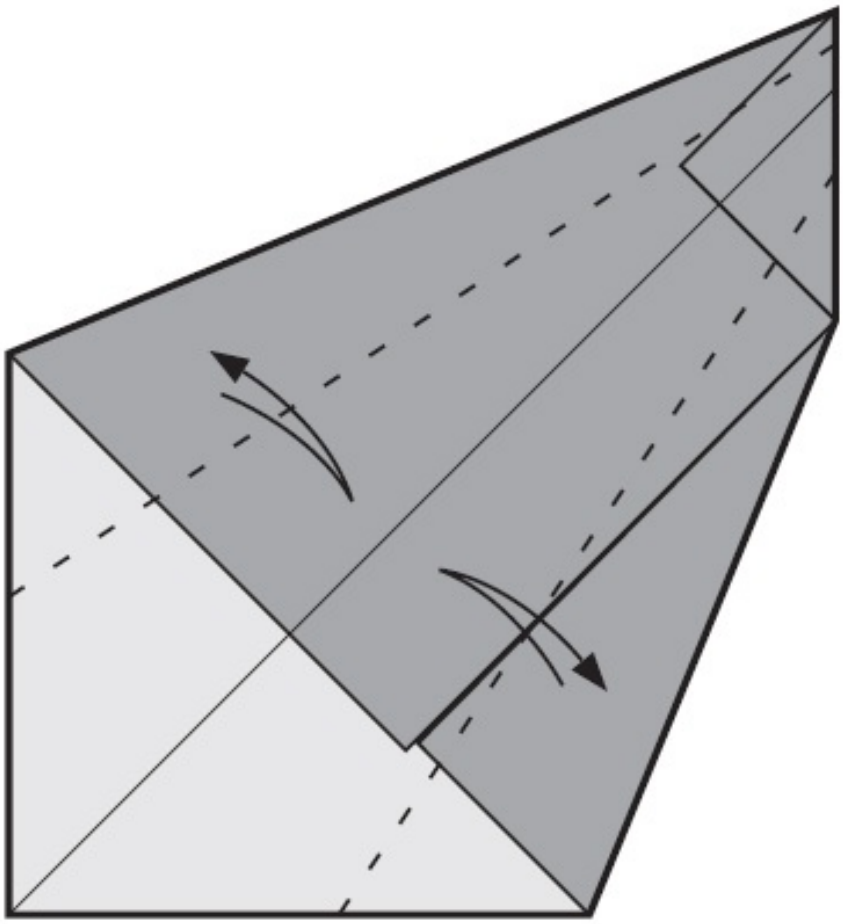
2 Make a pinch halfway down the left edge at 2, and then starting there, pull the bottom corner up to line 1 and make a pinch at 3.



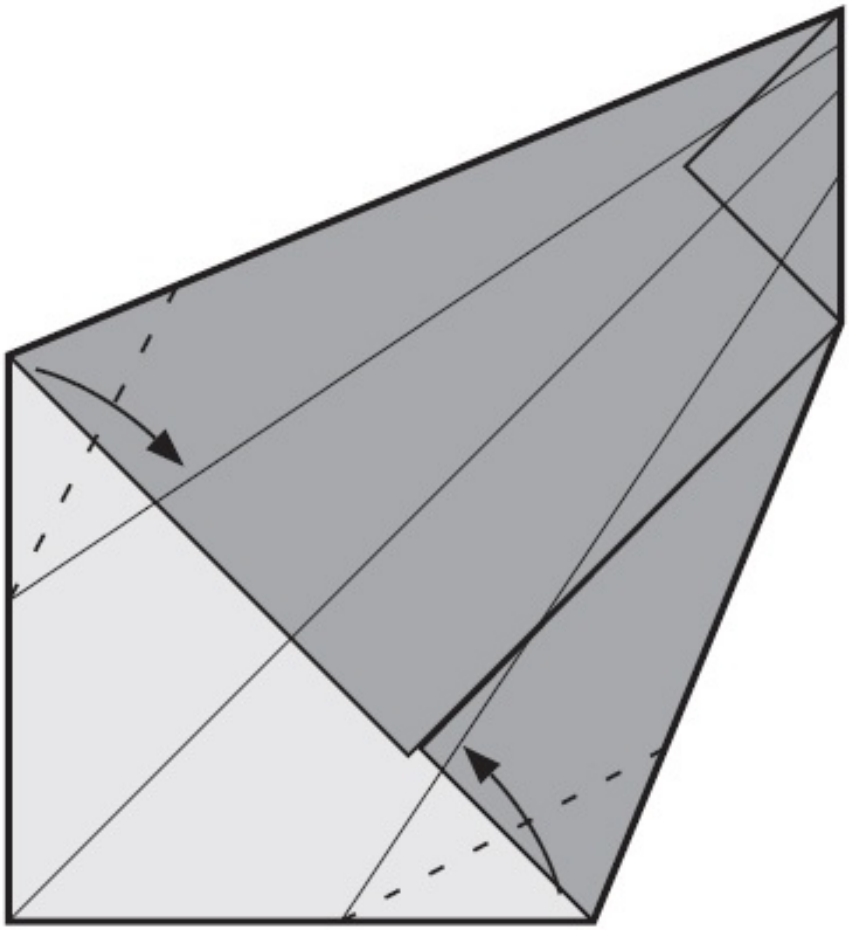
3 Fold down on line 4, starting at mark 2 and letting the edge just touch mark 3. Fold the other corner in on line 5 until the edges meet as in step 4.



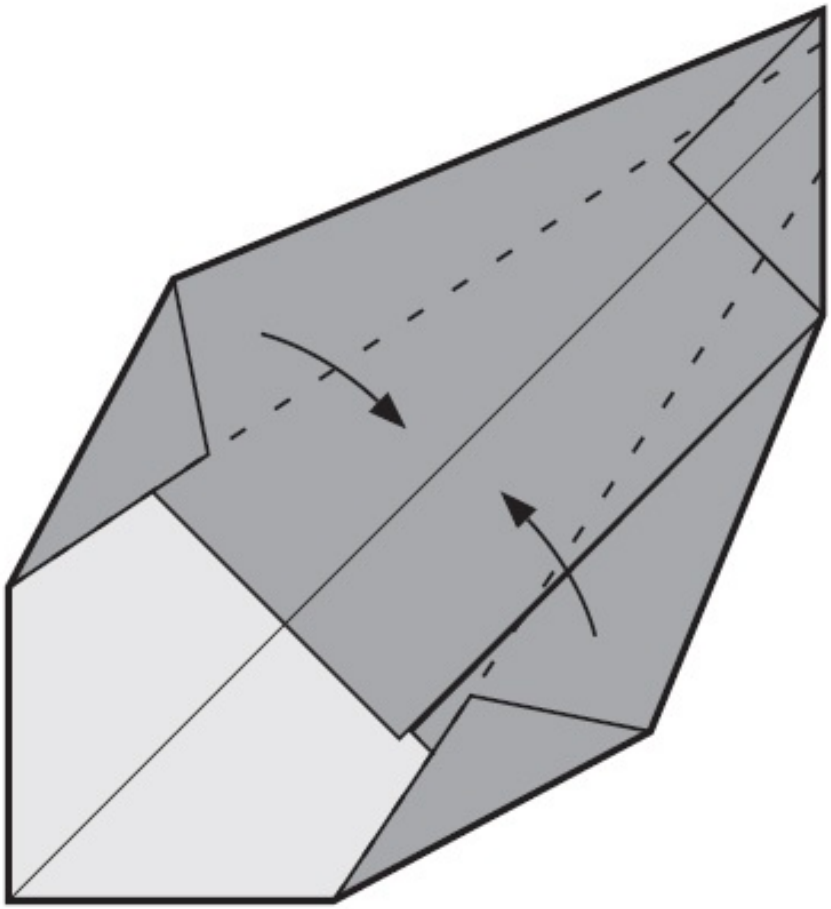
4 Fold the protruding corner in on line 6. Then, refold the center line to make it visible again.



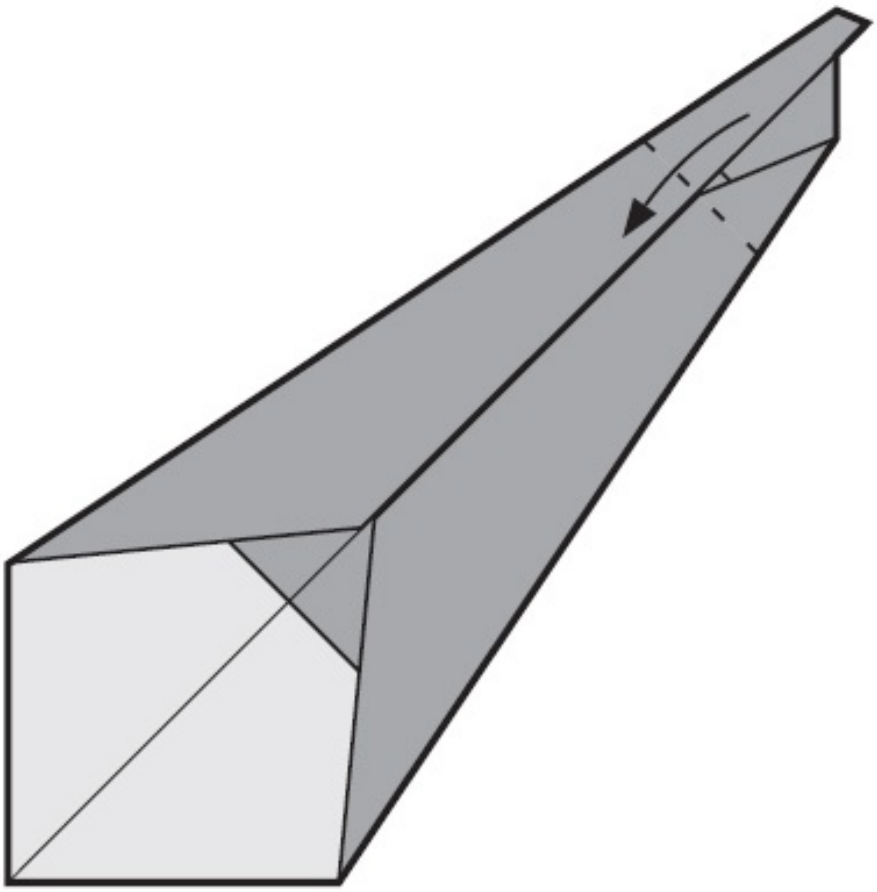
5 Fold and unfold the two sides on the 7 lines.



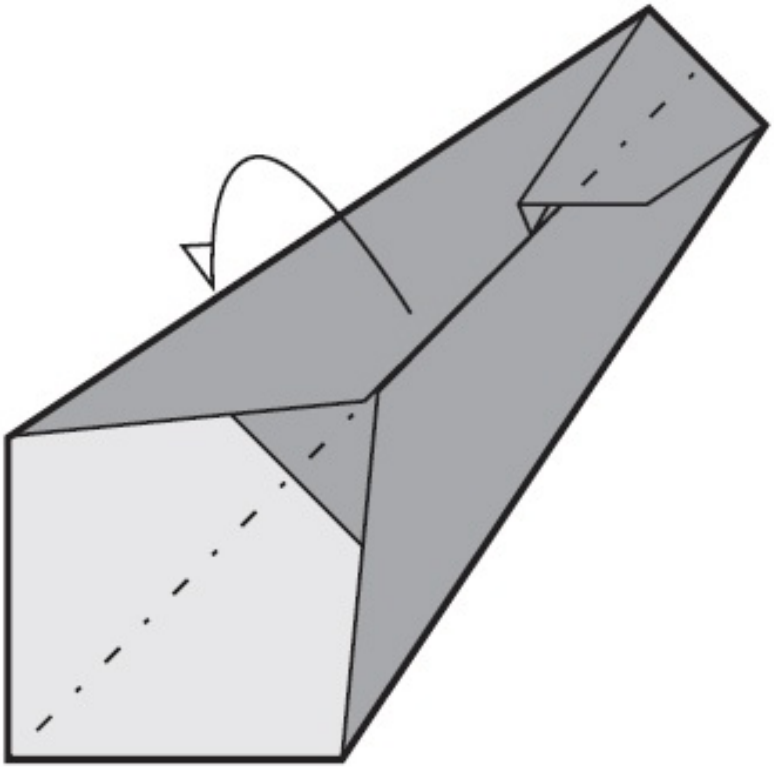
6 Fold the two corners in on the 8 lines.



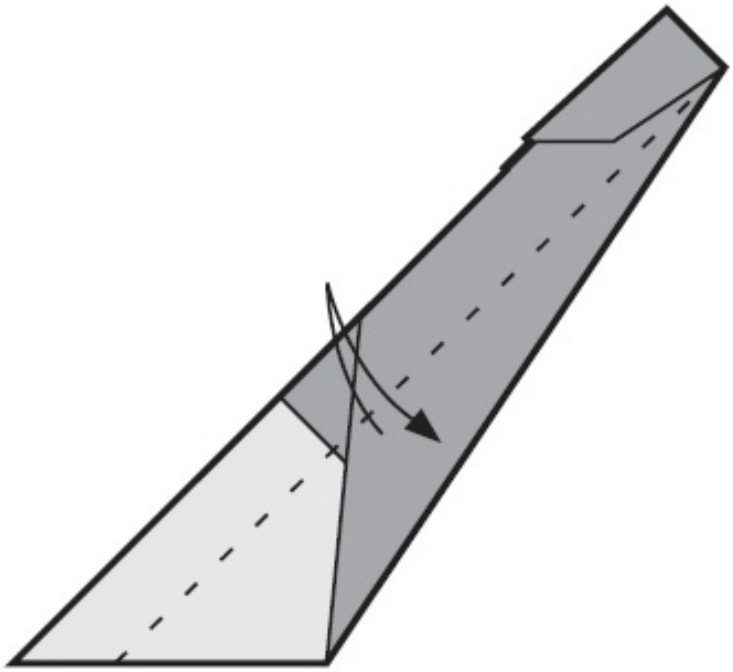
7 Refold the 7 lines.



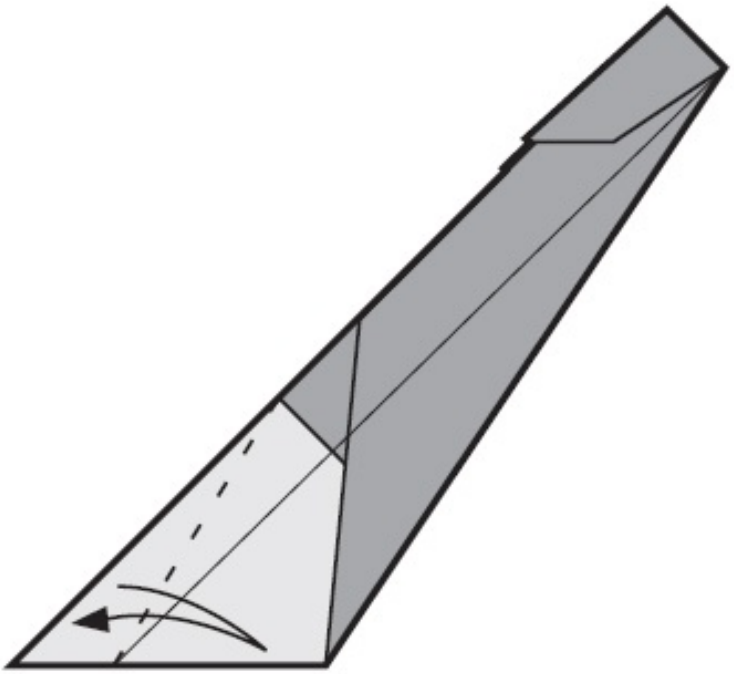
8 Fold down the nose on line 9. Note where the fold begins.



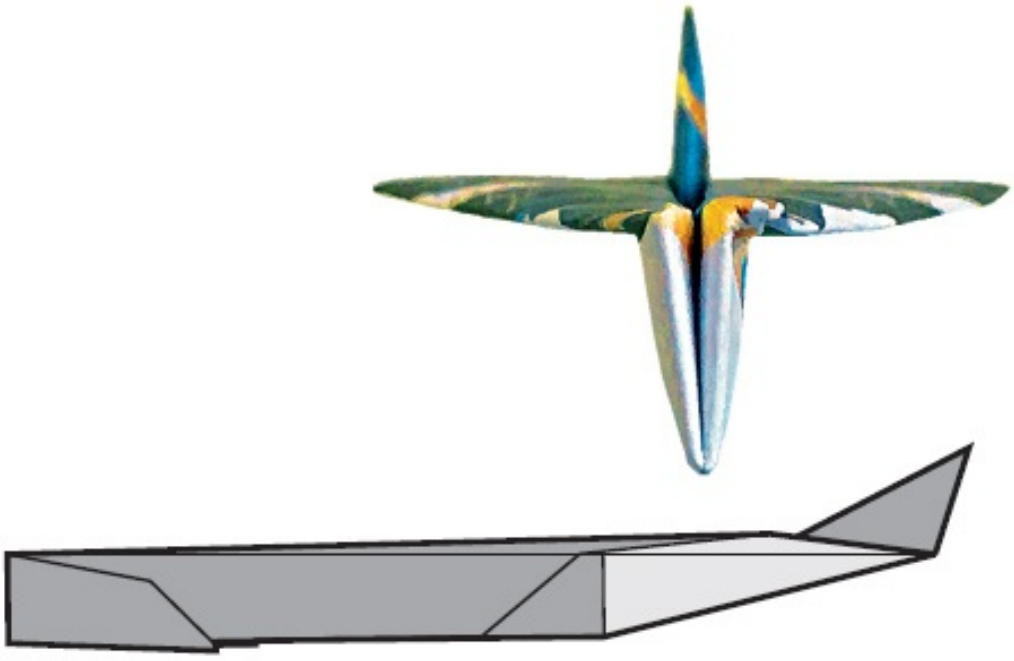
9 Fold the plane in half away from you.



10 Fold and unfold the wings on the 10 lines. The fold starts at the corner of the nose and is parallel to the bottom of the fuselage.



11 Fold, unfold, and reverse fold the rudder on line 11.



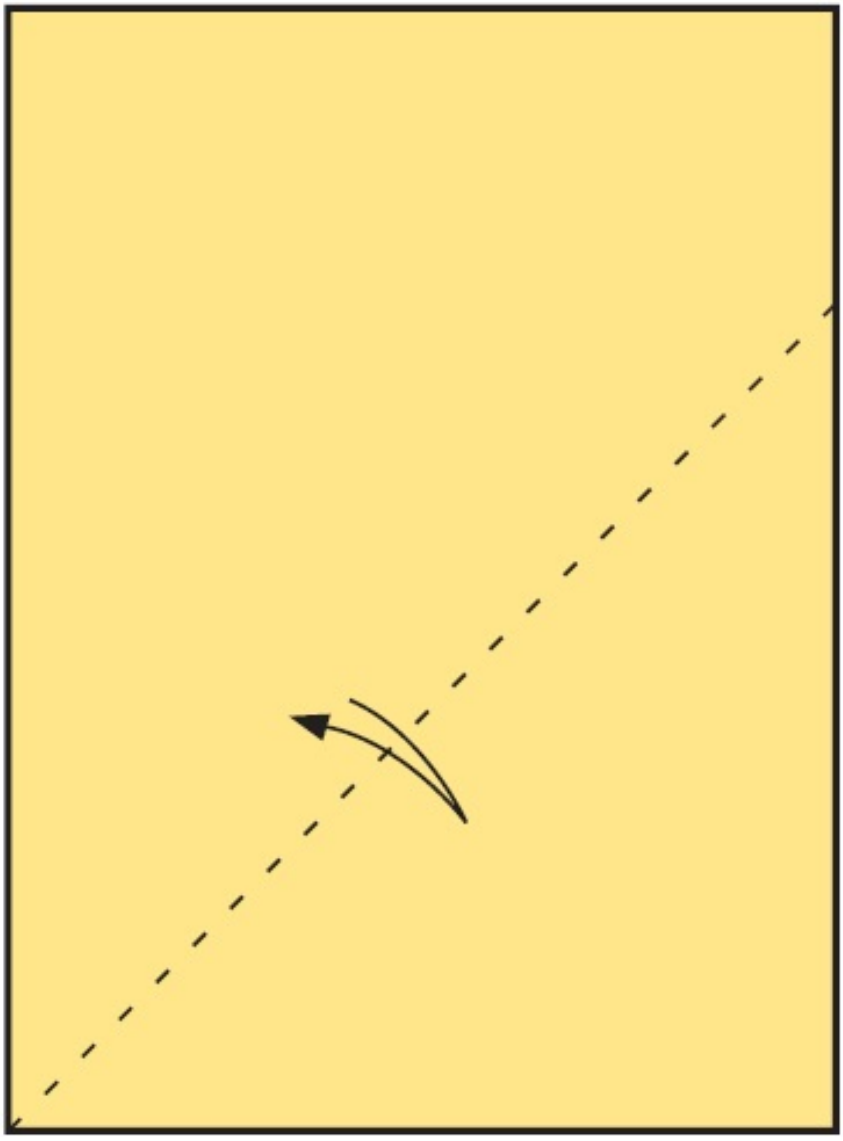
12 Open out the wings so that they look like this from the front and side. All done!

Airframe Note: This plane is sensitive to twists in the wings.

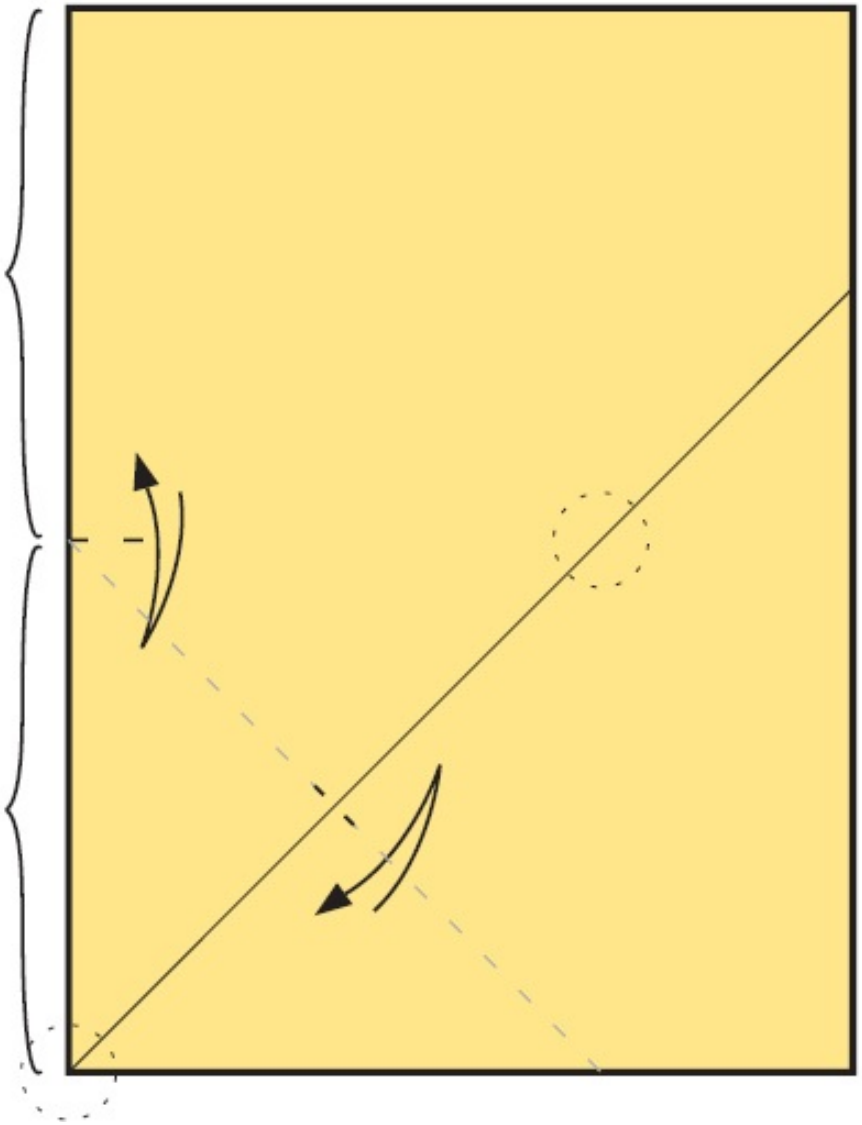
STAR JET

It's hard to add a stabilizer to the back of an origami airplane, because the amount of paper needed to create the shape usually makes the tail too heavy for flight. But this one grows out of the very large fin quite naturally. Star Jet climbs like mad with a strong throw.

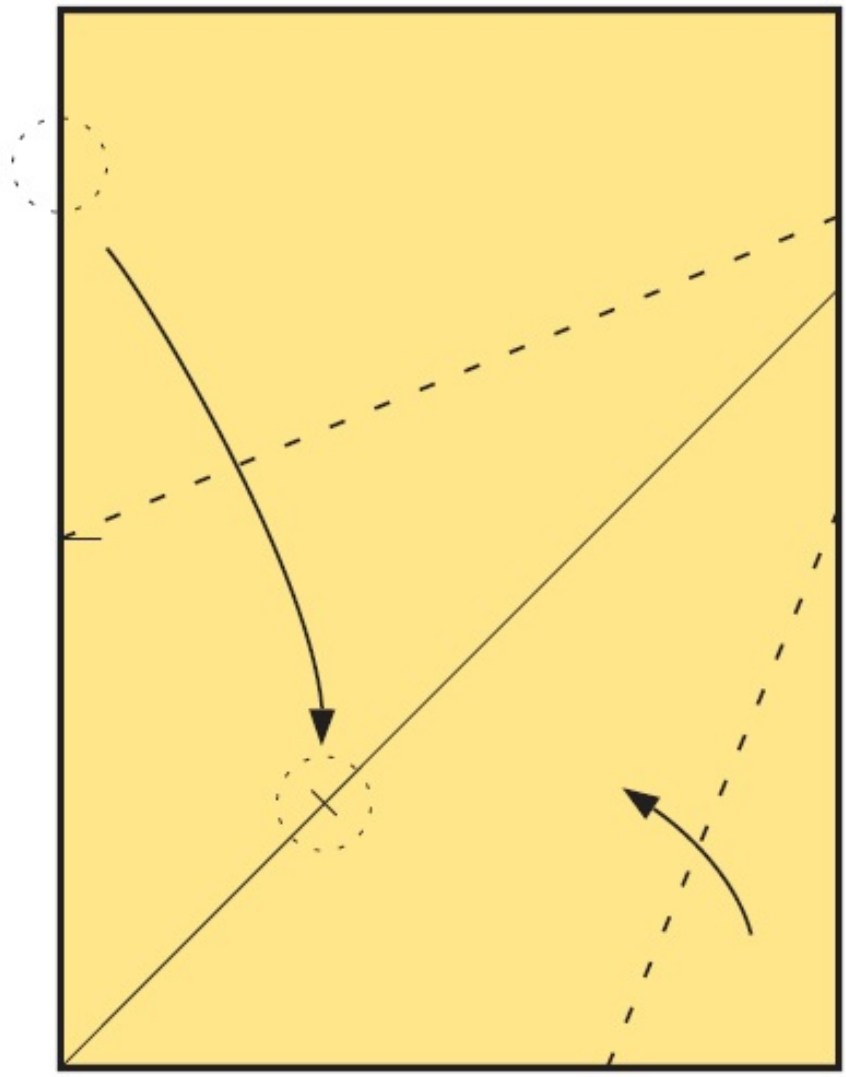
Author's Average
Distance Flown: 34 Yards



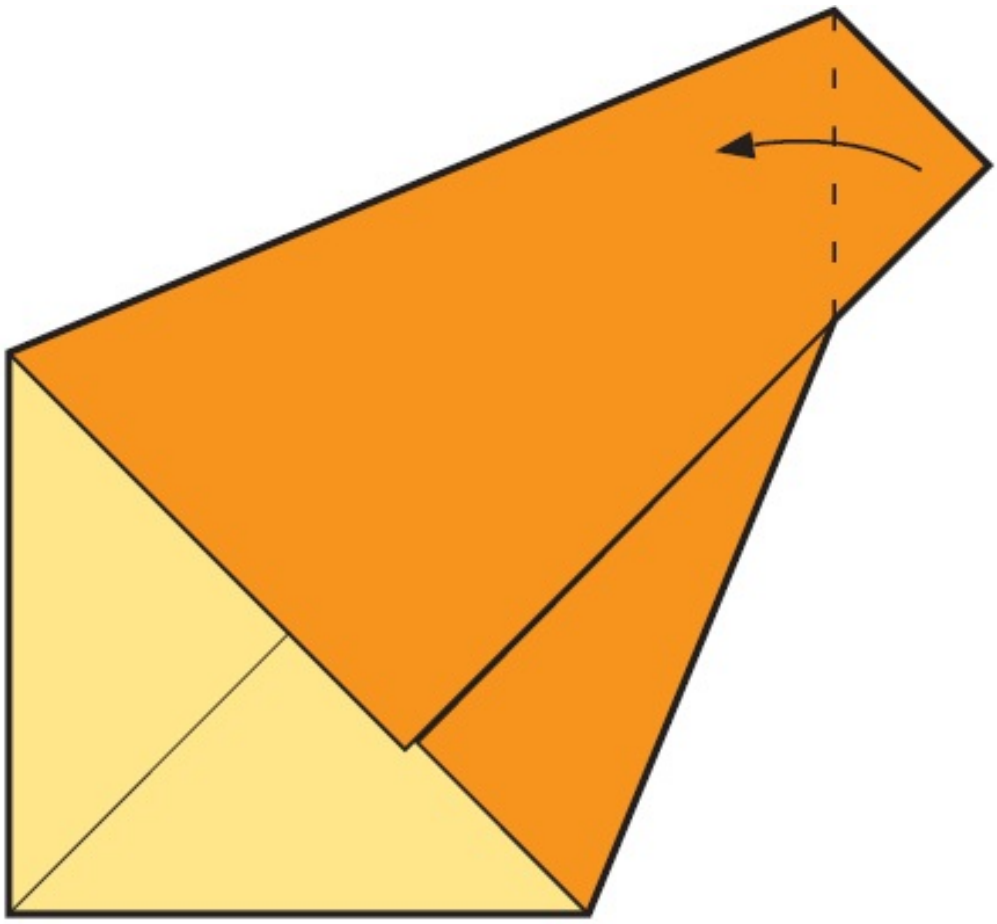
1 Start with the paper face down. Fold and unfold line 1, so the bottom edge just meets the left edge.



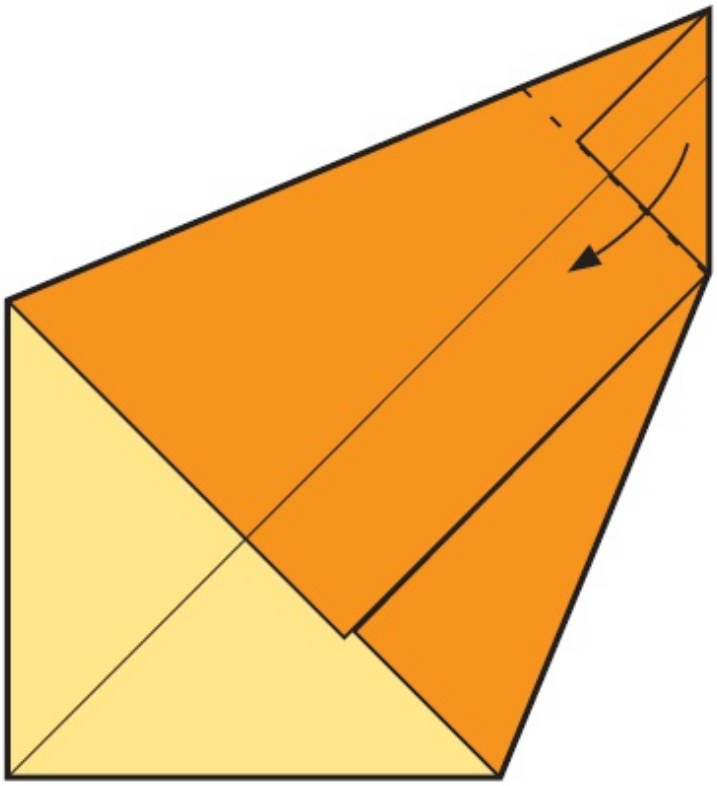
2 Make a pinch halfway down the left edge at 2, and then starting there, pull the bottom corner up to line 1 and make a pinch at 3.



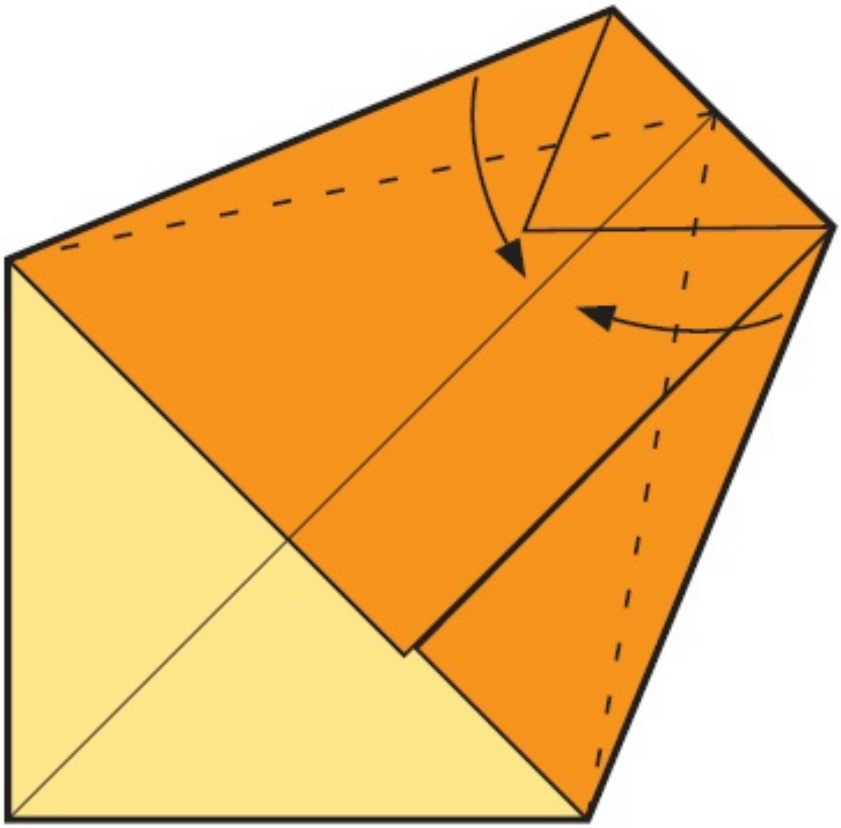
3 Fold down on line 4, starting at mark 2 and letting the edge just touch mark 3. Fold the other corner in on line 5 until the edges meet as in step 4.



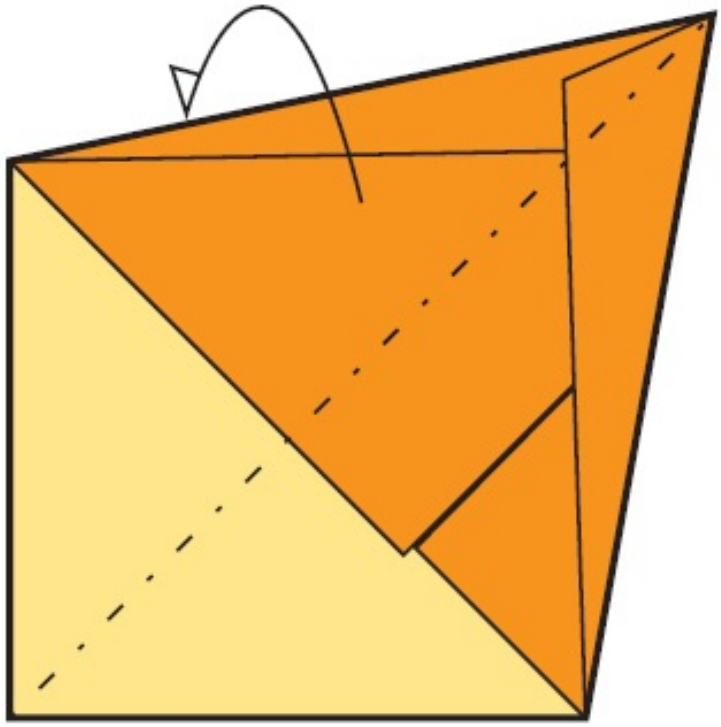
4 Fold the protruding corner in on line 6. Then, refold the center line to make it visible again.



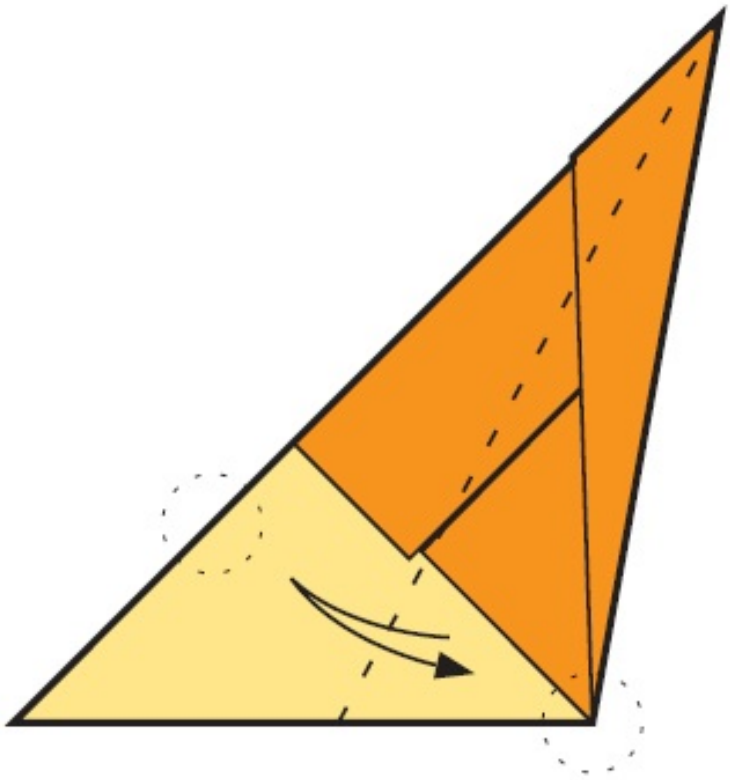
5 Fold down the tip of the nose on line 7.



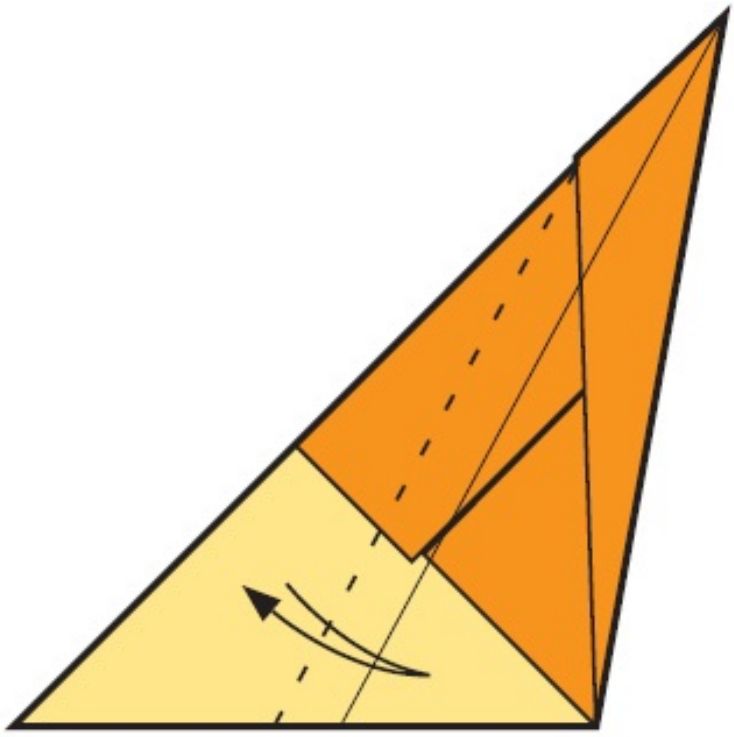
6 Fold the two corners in on the 8 lines.



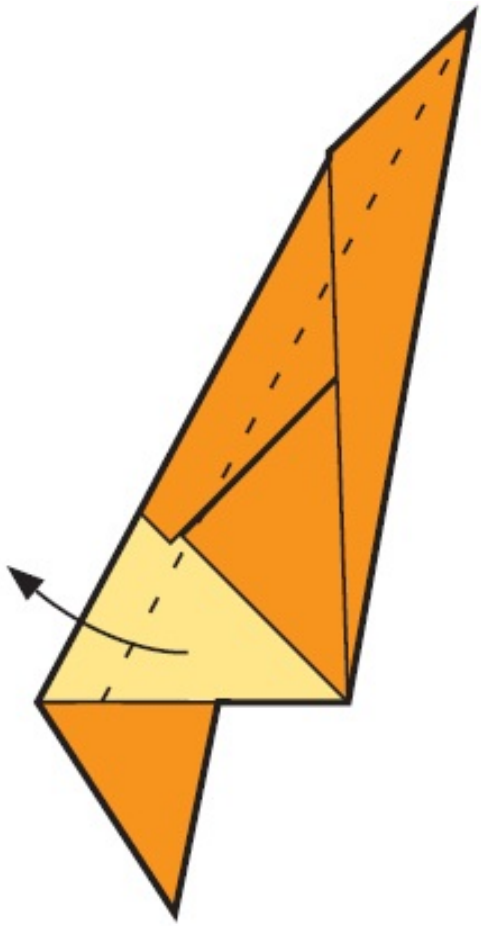
7 Fold the plane in half away from you.



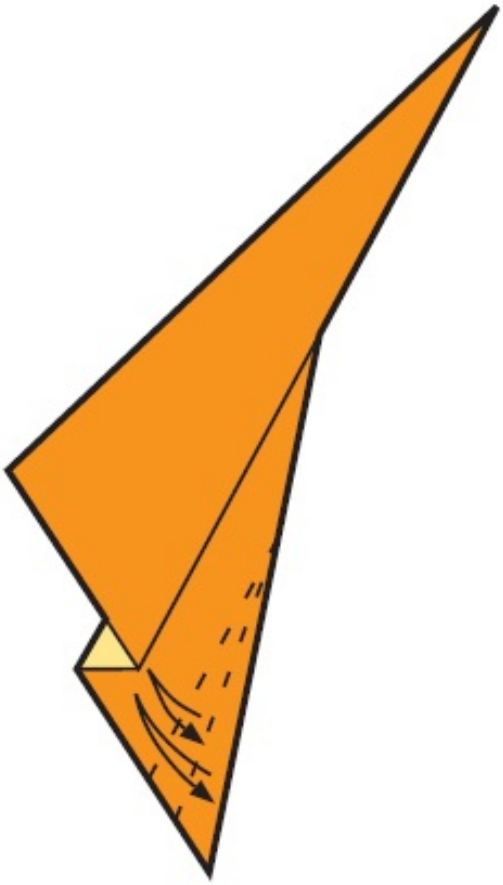
8 Fold and unfold the top wing on the 9 line, so the edge meets the center line. Fold the other wing to match the crease.



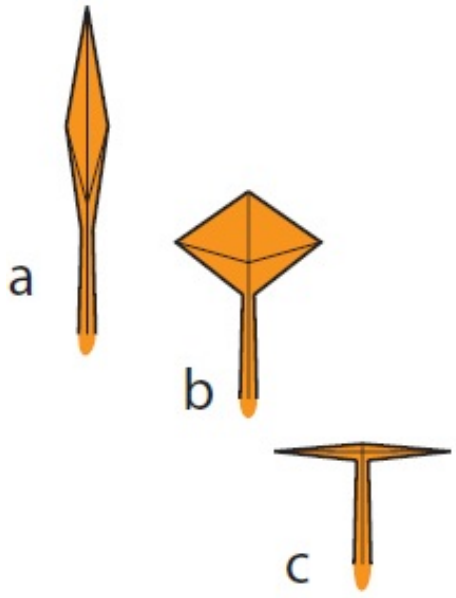
9 Fold, unfold, and reverse fold the rudder on line 10.



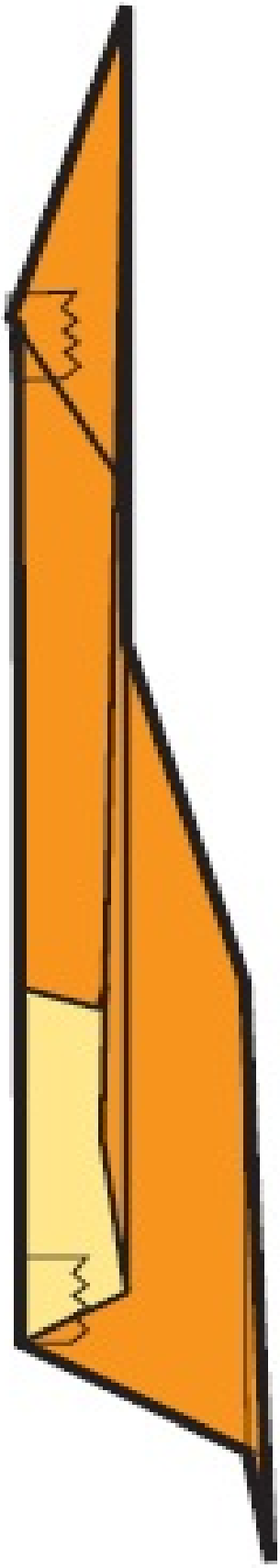
10 Refold the wings.



11 Fold and unfold the stabilizer on lines 11 and 12.



12 Push down the top of the rudder so the 12 line folds bulge out and make a T shape.

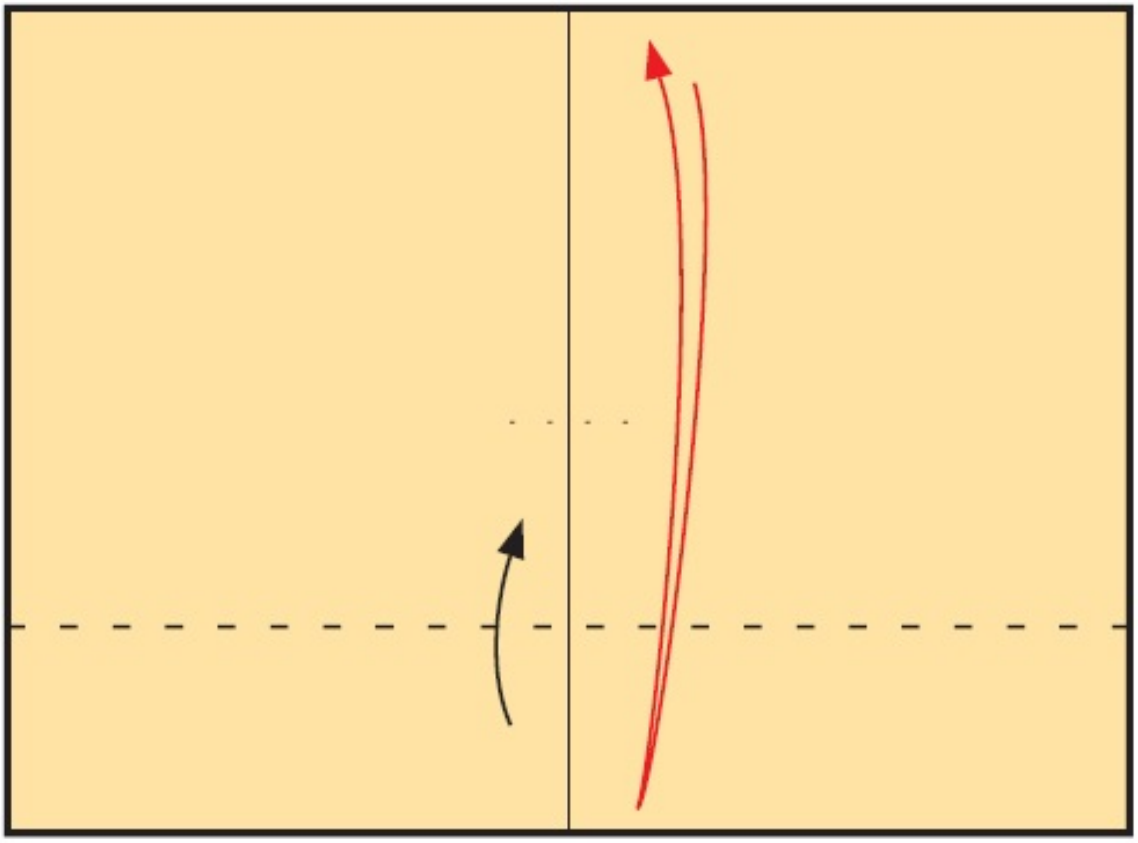


13 Use two small pieces of tape to hold the nose and tail together, and you're done!

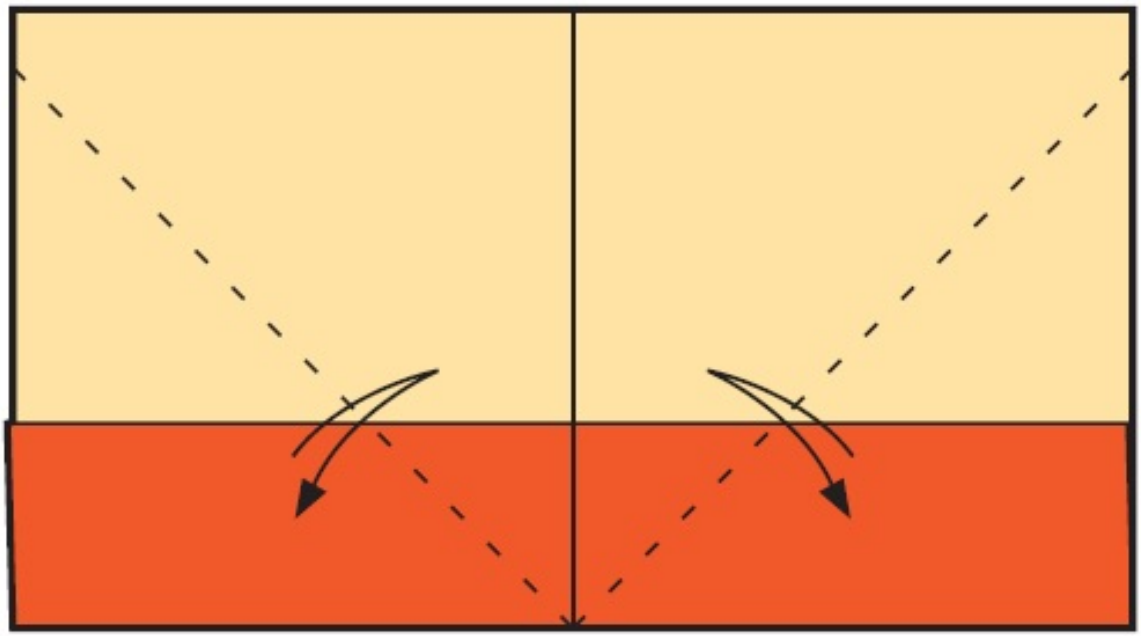
SPACESHIP RED

This plane might not set any records for distance or time aloft when thrown from the ground, but you might be surprised how far it will go if it's carried to the edge of space by a balloon and dropped high above the clouds!

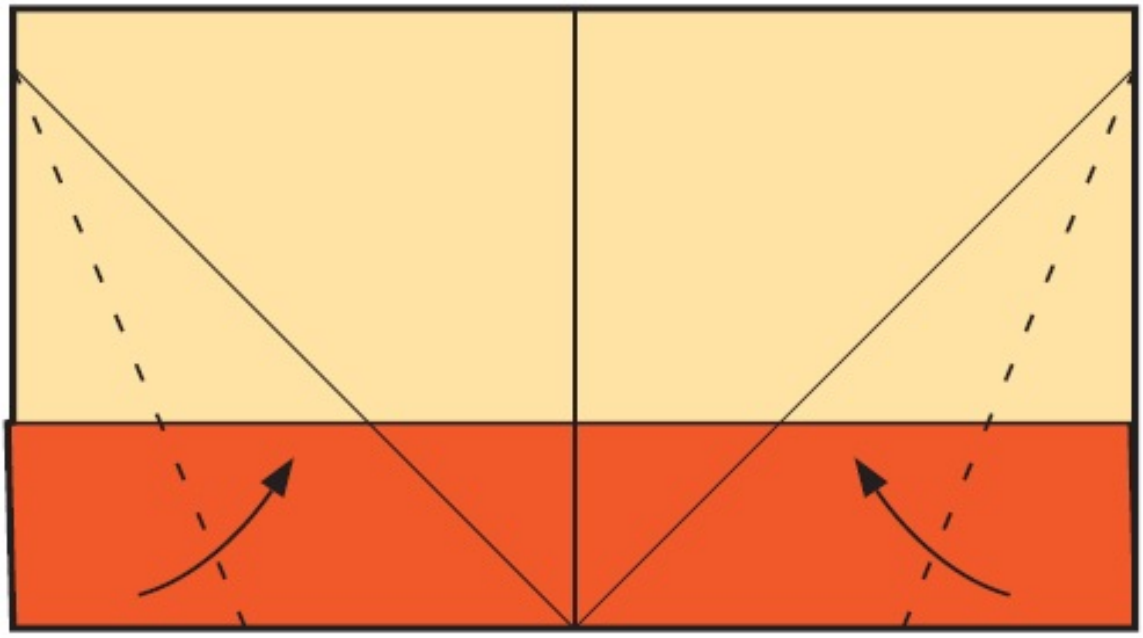
Author's Average
Time Aloft: 13 Seconds



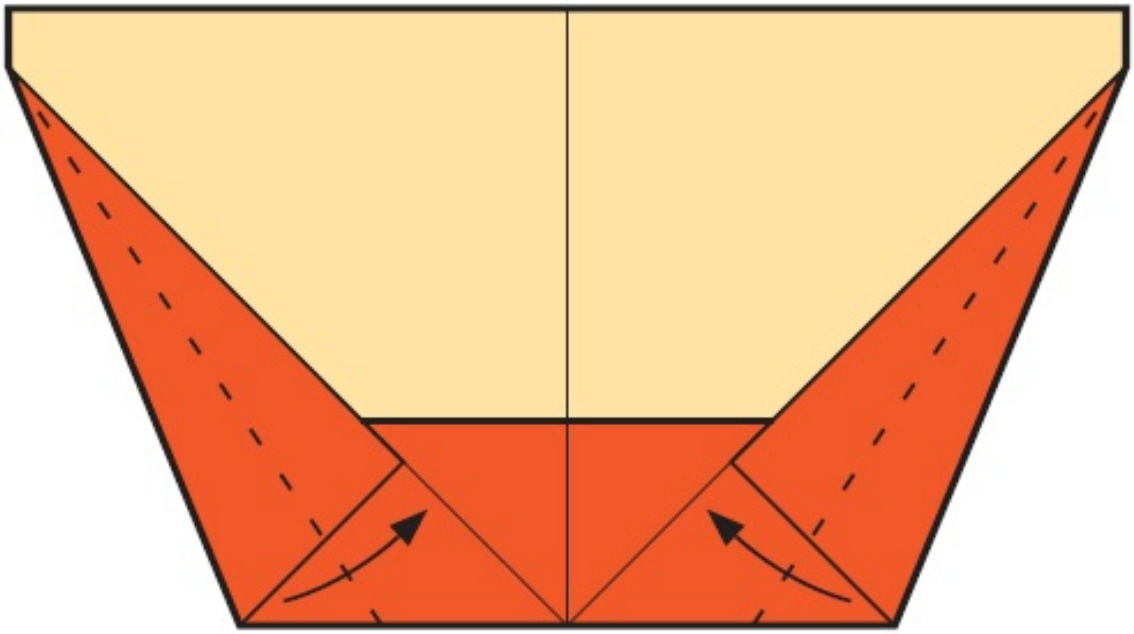
1 Start with the paper face down. Fold up the bottom edge on line 1 to the center of the paper.



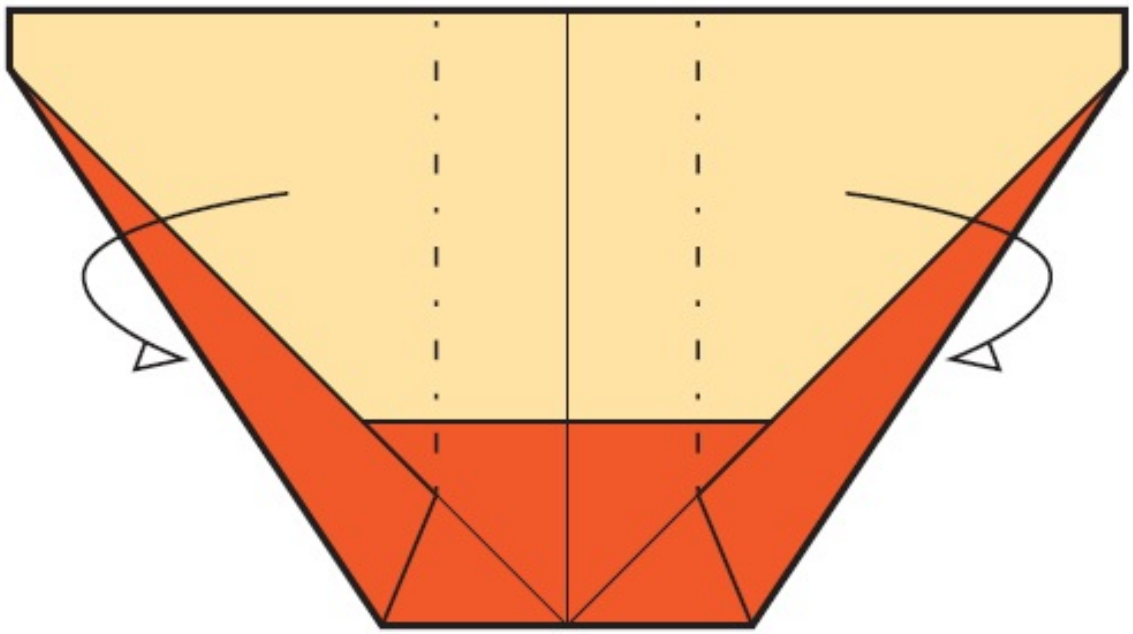
2 Fold the bottom corners to the center on the 2 lines, and unfold.



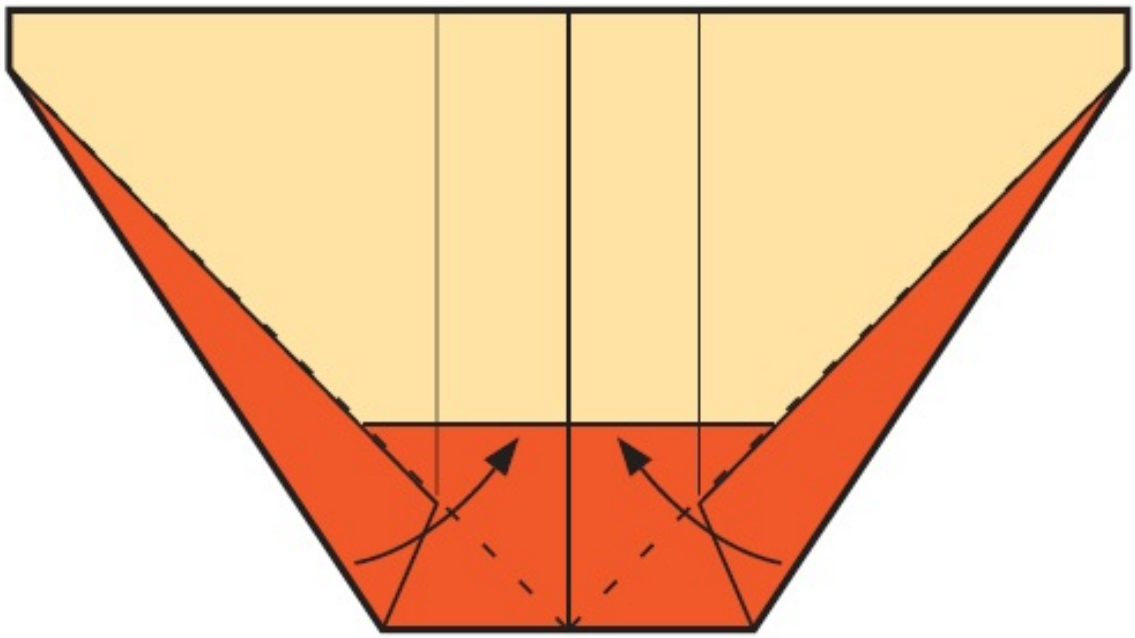
3 Fold the bottom corners on the 3 lines, so they just meet the creases you made in the last step.



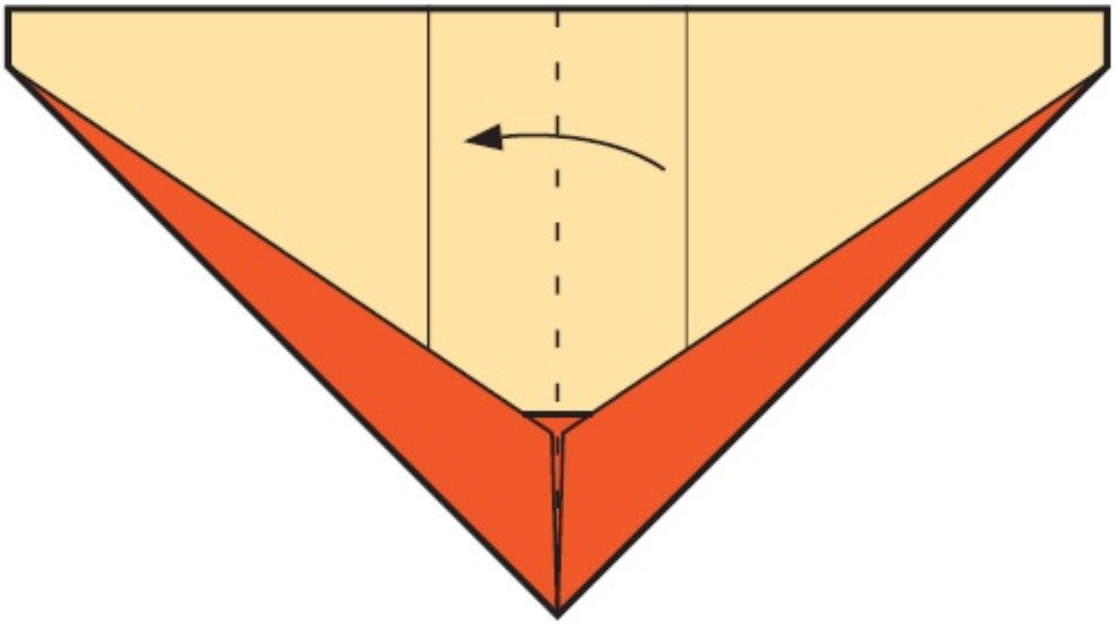
4 Fold the new corners on the 4 lines, so they just meet the same crease.



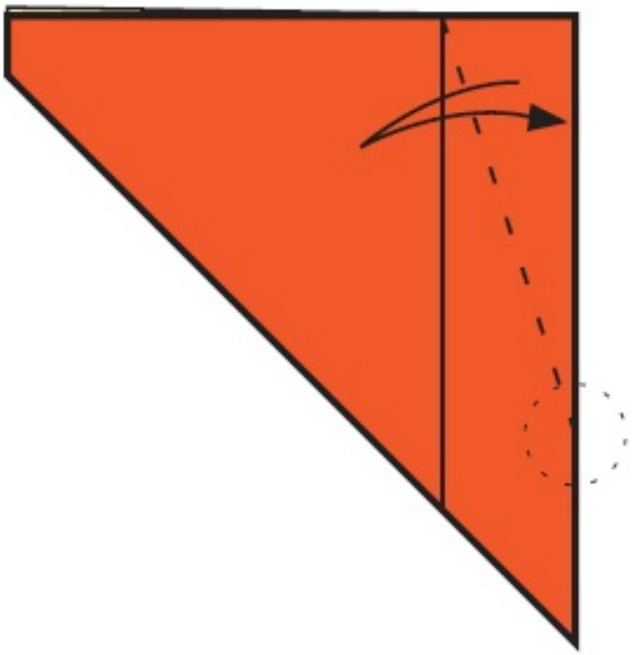
5 Fold the paper back on the 5 lines, starting at the corner shown and parallel to the center line.



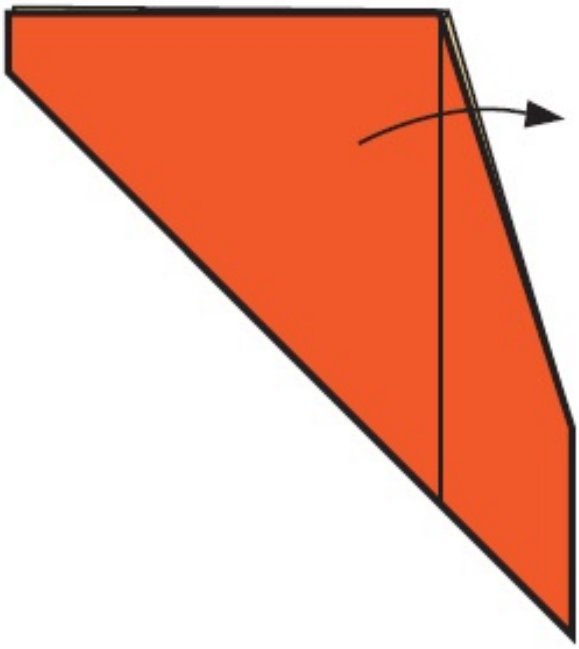
6 Refold the corners on the 2 lines.



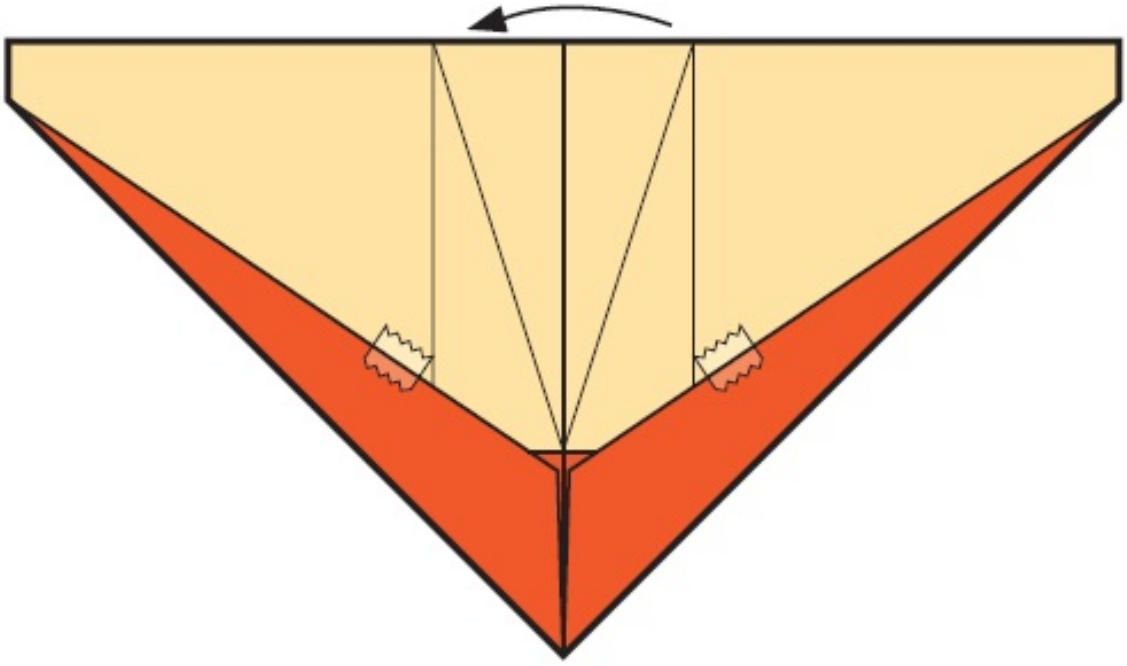
7 Fold the plane in half towards you.



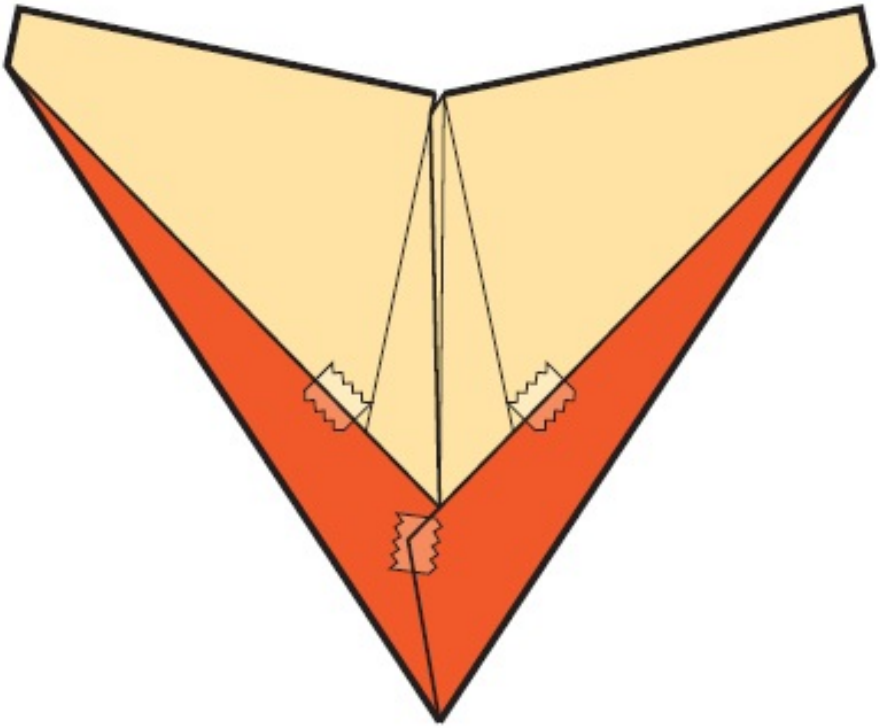
8 Fold, unfold, and reverse fold the rudder on line 6.



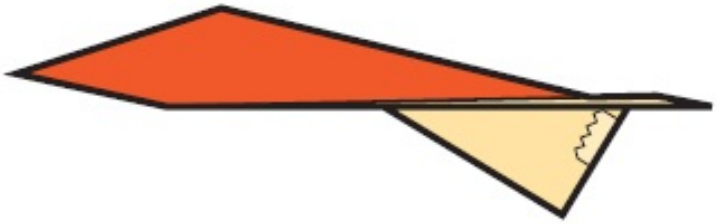
9 Open the plane out again.



10 Place two small pieces of tape in the places shown. Begin squeezing the tail together, with the rudder recreating the reverse fold.



11 Use a small piece of tape to fasten the overlapping nose flaps, as shown.

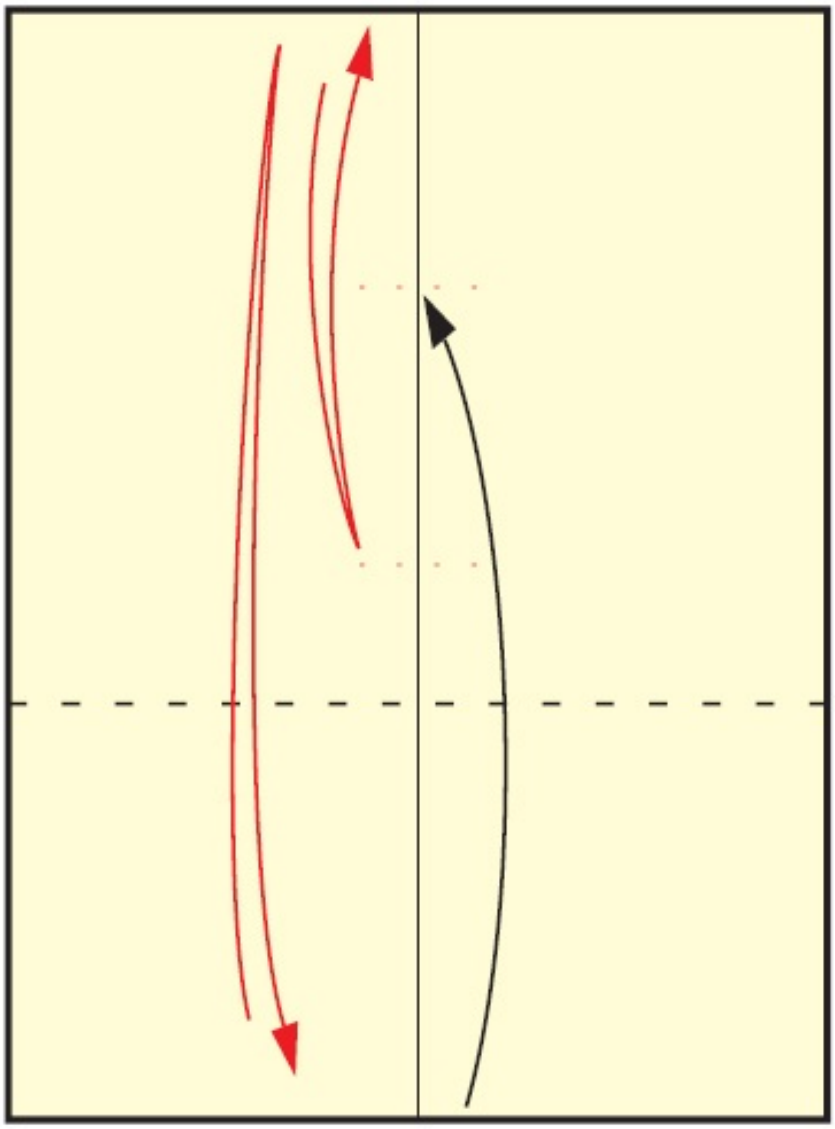


12 Tape together the back edge of the rudder close to the wing, and you're done!

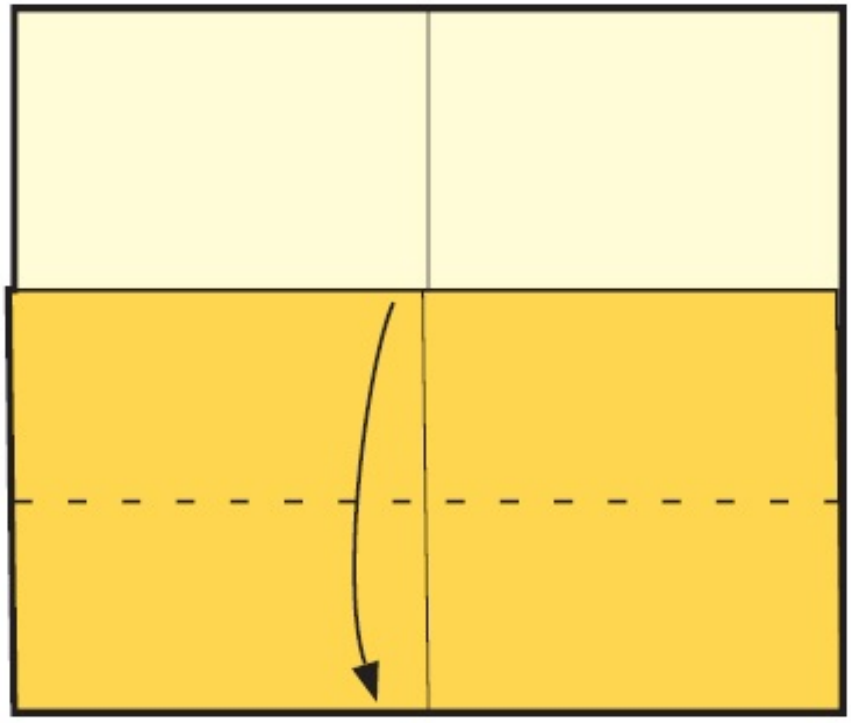
SPACESHIP GOLD

This plane is similar to the space shuttle-style airplanes Takuo Toda put in a hypersonic wind tunnel and planned to fly from the International Space Station. This plane is a bit simpler to fold, but still out of this world!

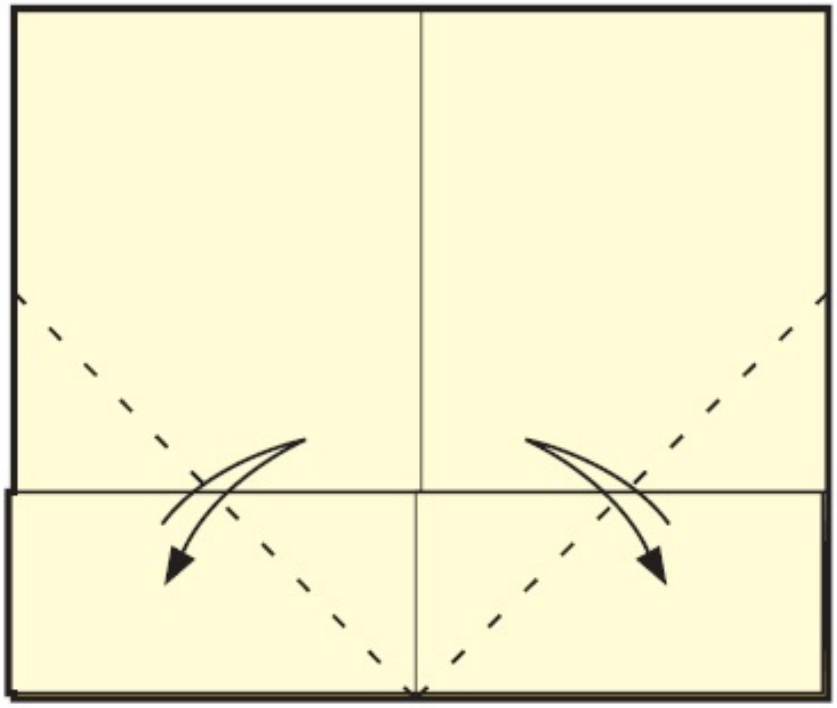
Author's Average
Time Aloft: 15 Seconds



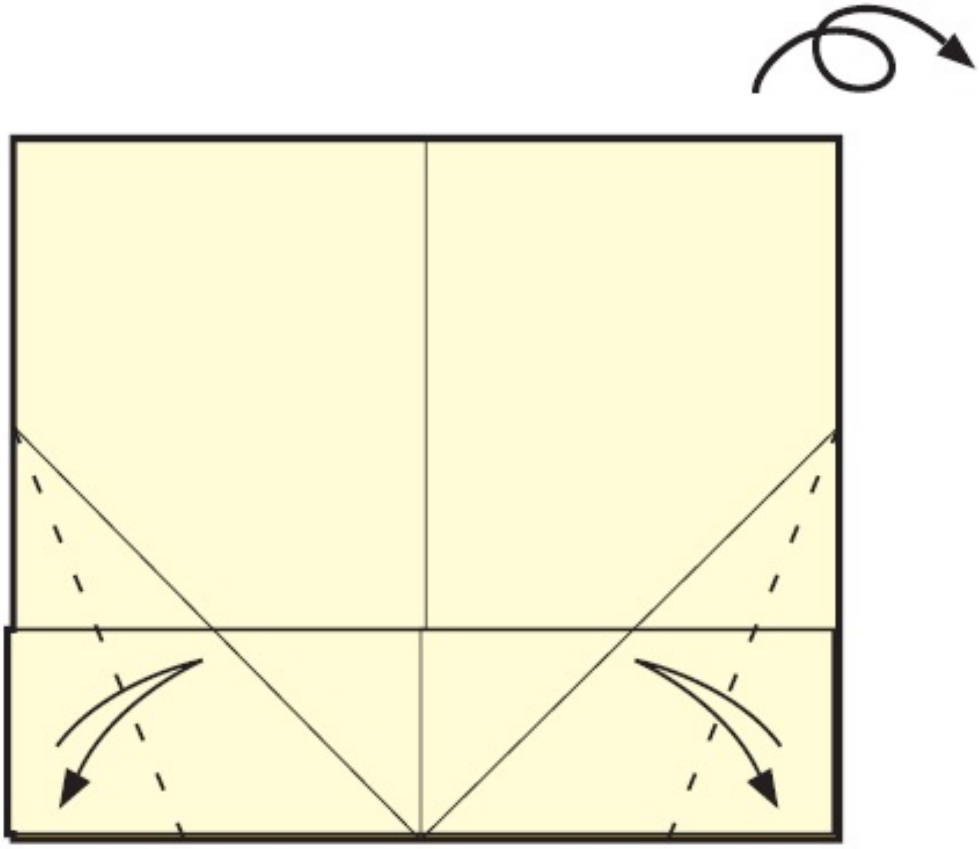
1 Start with the paper face down. Fold up on line 1. The red arrows show how to find where to make the fold.



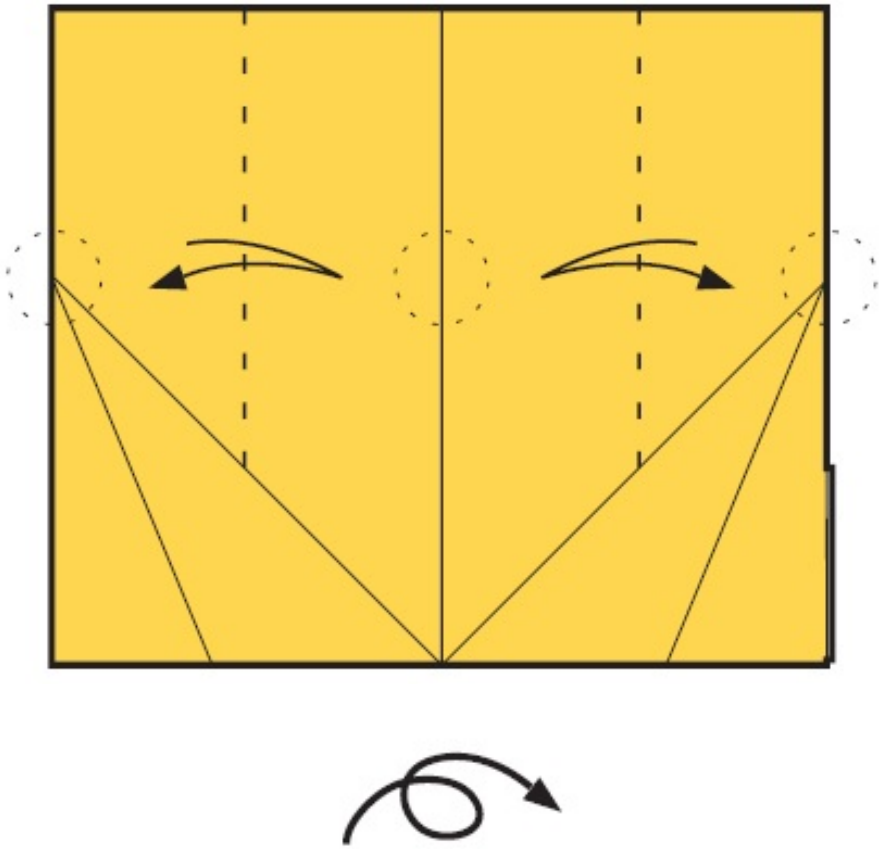
2 Fold the loose edge back down to the bottom edge on line 2.



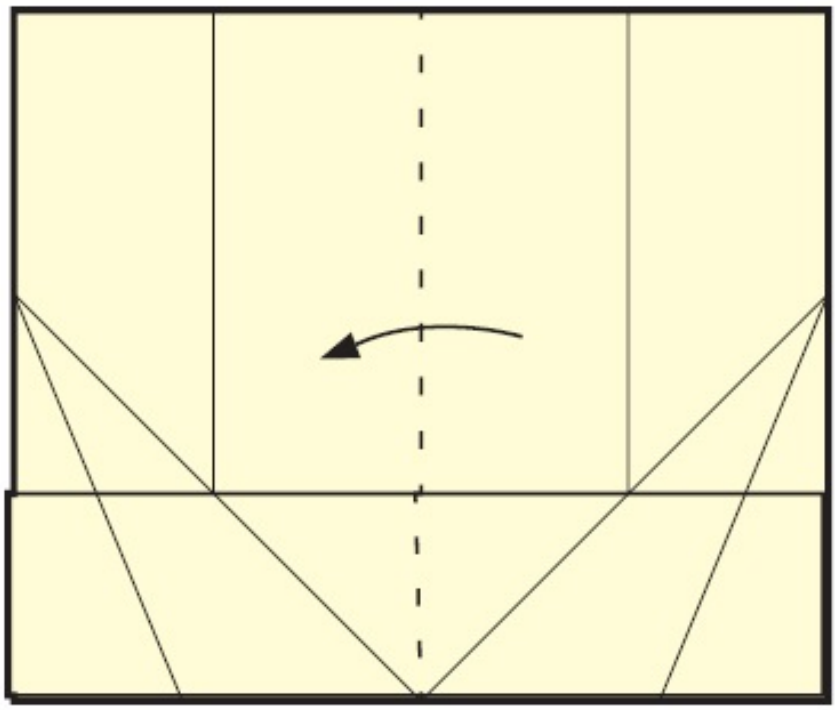
3 Fold the bottom corners up to the center line on the 3 lines, and unfold them.



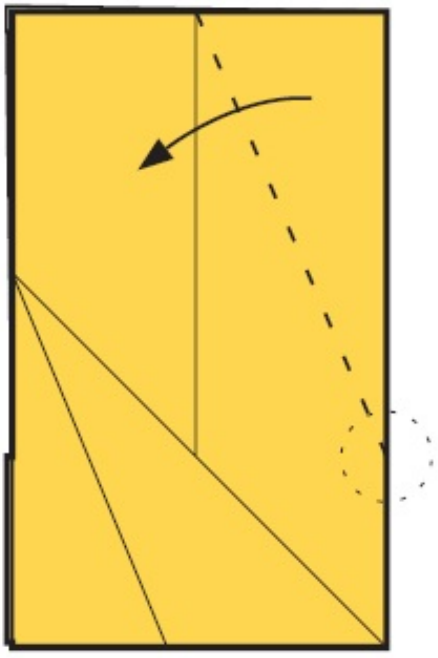
4 Fold the corners in on the 4 lines to the creases you just made. Unfold again, and flip the plane over horizontally.



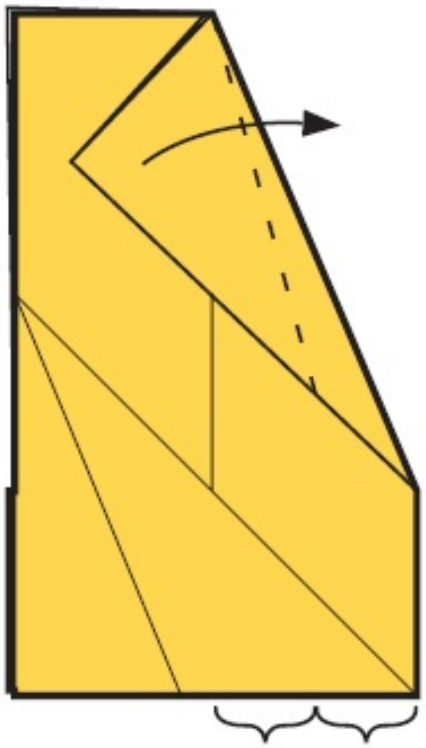
5 Fold the sides to the center on the 5 lines. The creases go only as far as line 3. Unfold again and flip the paper over.



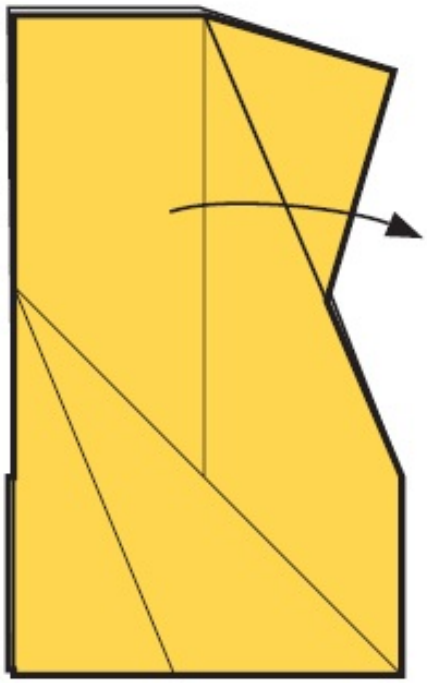
6 Fold the paper in half towards you.



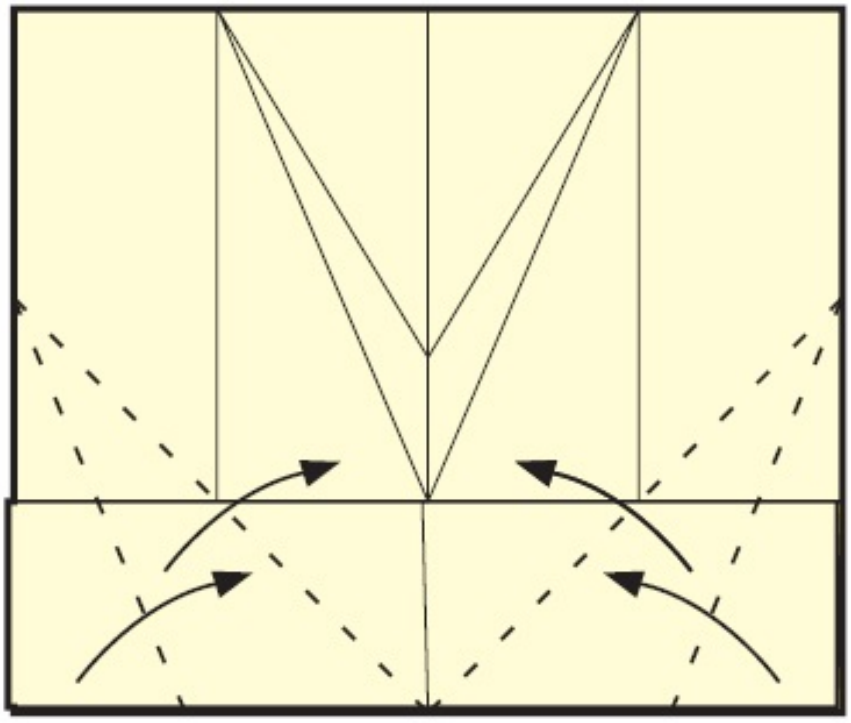
7 Fold the rudder down on line 6, starting at the edge of the fold on the inside.



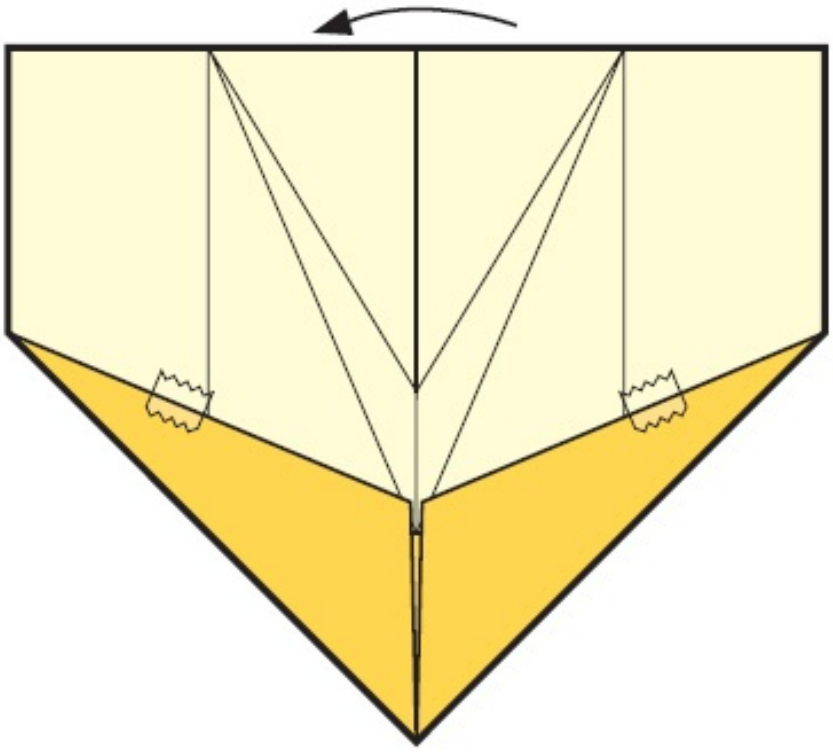
8 Fold back on line 7, starting halfway between the corner and the line 5 crease.



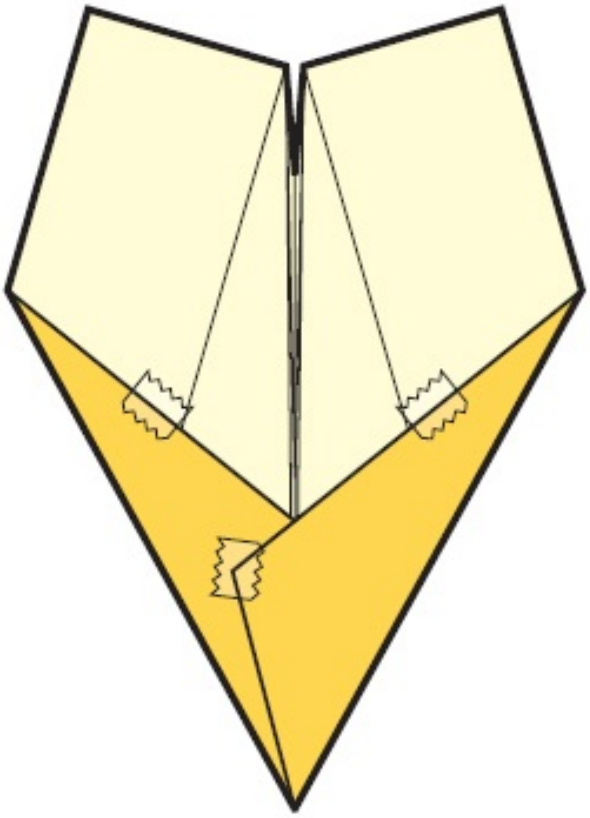
9 Reverse the last two folds so they look like this. Open the whole plane out again.



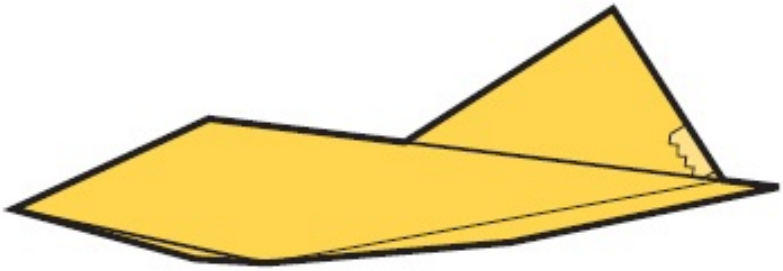
10 Refold the corners on the 4 lines, and then again on the 3 lines.



11 Place two small pieces of tape in the places shown. Begin squeezing the tail together, with the rudder recreating the reverse folds.



12 Use a small piece of tape to fasten the overlapping nose flaps, as shown.



13 Tape together the back edge of the rudder close to the wing, and you're done!

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